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RADIATION AT DIFFERENT TEMPERATURES.

By CAPTAIN JOHN ERICSSON.

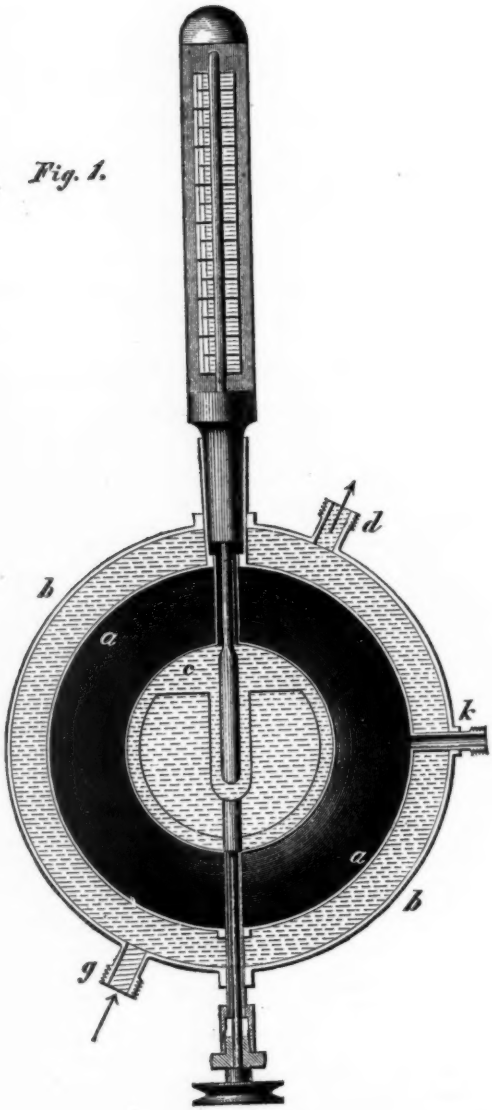
From "Nature."

Balfour Stewart states in his "Elementary Treatise on Heat," that "Newton was the first to enunciate his views on the cooling of bodies. He supposed that a heated body exposed to a certain cooling cause would lose at each instant a quantity of heat proportionate to the excess of its temperature above that of the surrounding air." In order to prove the fallacy of Newton's supposition, Prof. Stewart presents the following extract from the work of MM. Dulong and Petit:—

Excess of temperature of the thermometer. °C.	Velocity of cooling. °C.
240	10.69
220	8.81
200	7.40
180	6.10
160	4.89
140	3.88
120	3.02
100	2.30
80	1.74

"We see at once from this table," says Prof. Stewart, "that the law of Newton does not hold, for according to it the velocity of cooling for an excess of 200 deg. should be precisely double of that for an excess of 100 deg.; now we find that it is more than three times as much." The author of the "Elementary Treatise on Heat" thus assumes that the velocity of cooling established by Dulong and Petit, represents the radiant energy or quantity of heat transmitted by the radiator. Consequently, the amount of energy at 200 deg. is assumed to be $\frac{10.69}{1.74}=$ 6.14 times greater than at 80 deg.; while, agreeably to Newton's law, the increase of radiant energy should be proportional to the differential temperature, viz., $\frac{240}{80}=3$ times that of the tabulated temperature of 80 deg. Modern research having established that radiant heat is energy amenable to the laws of dynamics, it may be demonstrated that the deviation from the Newtonian doctrine assumed by Dulong and Petit, is groundless; but, before considering the theory, let us examine the practical result of recent elaborate experiments conducted with an apparatus containing the spherical radiator adverted to in the preceding article on Solar Temperature (vol. v., pp. 505–507). The accompanying illustration (Fig. 1) represents a vertical section of the said apparatus, *a* being a spherical vessel 5 in. in diameter, suspended within an exterior casing *b*, filled with water. A spherical radiator, *c*, 2.75 in. in diameter, composed of very thin copper, charged with water and coated with lamp-black, is sustained in the centre of the sphere *a* by means of tubes applied above and below. The upper tube is large enough to admit the bulb of a thermometer, the lower one being only suffi-

Fig. 1.



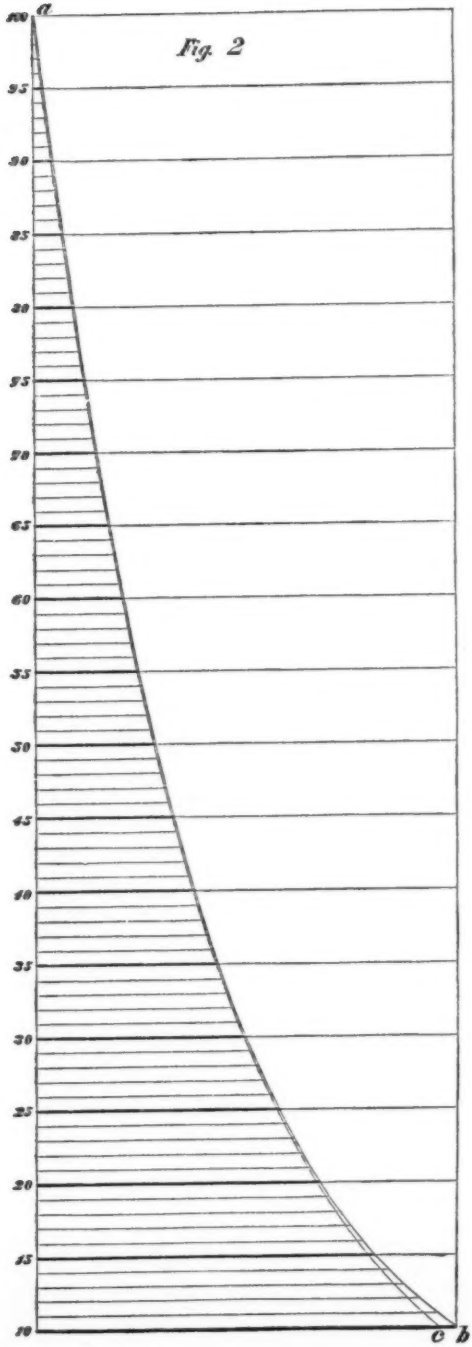


Fig. 2
a
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
c
b

ciently large to accommodate a small axle, to which is attached a paddle-wheel, provided with curved paddles, arranged in such a manner that the bulb of the thermometer may be inserted considerably beyond the centre of the sphere, as shown in the illustration. The external casing *b*, is provided with nozzles, *g* and *d*, to which tubes are attached for circulating cold water through the annular space during experiments. The air is exhausted from the spherical enclosure through the tube *k*, which passes across the annular space. It will be evident that the centrifugal action of the paddles of the wheel applied within the radiating sphere will produce a continuous current from the centre towards the circumference, the fluid successively passing over and coming in contact with the inside of the thin shell, then returning to the centre to be again thrown off by the centrifugal action. The rotary motion of the water, kept up without intermission round the cylindrical bulb of the thermometer, will evidently render its indication prompt and reliable. It is hardly necessary to observe that the rapid presentation of fresh particles of water promoted by the action of the paddles, will effectually prevent the reduction of temperature to proceed faster at the circumference than at the centre, the radiation at the surface, in virtue of the continuous interchange of particles, affecting almost simultaneously every molecule within the sphere. Consequently the total energy of radiation will be rendered available in reducing the temperature of the contents of the radiator, while the central thermometer will indicate at every instant the precise degree of temperature of the entire mass.*

The mode of conducting the experiment will be seen by the following statement:—A wooden cistern containing 16 gallons, charged with water and crushed ice, is connected by flexible tubes to the nozzles *g* and *d* on opposite sides of the annular space, a pump being applied between the cistern and the said nozzles, by means of which the cold water is forced through the apparatus and then returned to the cistern.

In view of the great importance of the question at issue, the investigation has been conducted with the utmost care, four operators having invariably been employed during the experiments, the labor being thus divided: 1st operator regulates the temperature of the water in the cistern by continual agitation and supply of crushed ice from time to time; 2d operator works the pump at a uniform rate; 3d operator turns the paddle-wheel and reads the thermometer under a magnifying glass, calling time for each degree at the instant when the top of the mercurial column is covered by half the thickness of the line on the scale. Lastly, the 4th operator, provided with a Casella chronograph, records the time called. It will be seen presently that, notwithstanding this procedure, there is a slight discrepancy in the ratio of temperature and time, viz., the increment of time for each degree is not regular. Obviously the most practised eye cannot determine exactly at what moment the top of the falling column is half covered by the line on the thermometric scale. Again, a perfectly graduated thermometer cannot be obtained. But the discrepancy referred to in reality only disfigures the record, since the computations are based on mean time. Referring to the accompanying table, (see p. 118) it will be seen that the rate at which the spherical radiator cools has been recorded separately for each degree of differential temperature from 100 to 10 deg., the enclosure being maintained at a constant temperature of 33 deg. Regarding the construction of the table, it will suffice to state that the time entered in the fourth column is that shown by the chronograph. It will be evident on reflection that the increment of time for each successive degree of differential temperature expresses very nearly the rate of cooling; but, the recorded times being irregular, from causes already pointed out, the true increment cannot be determined without ascertaining the mean time recorded by the chronograph. This mean time will be found in the fifth column, the true increment, viz., the number of seconds during which the temperature of the radiator falls one degree, being entered in the last column.

Let us now examine the accompanying diagram (Fig. 2), in which the ordinates of the curve *a b* represent the observed time for each degree of differential temperature, while the ordinates of the curve *a c* represent the corrected time. The diagram hav-

* It might be supposed that the motion of the water within the radiating sphere, produced by the action of the paddle wheel, will occasion an elevation of temperature tending to render the indication of the central thermometer inaccurate. The requisite speed of the wheel being 30 turns per minute, experiments have been made to ascertain if at that rate heat is produced; but no elevation of temperature has been observed. The diameter of the wheel being 2.37 in., the maximum speed of the particles of water produced by the rotation is scarcely 3.8 in. per second, a velocity too small to generate appreciable heat.

ing been constructed with the utmost exactness, in accordance with the temperature and time in the table, mere inspection will show that the observed and corrected times have produced curves nearly identical. Agreeably to Newton's law, the rate of cooling is proportional to the excess of temperature of a body above that of the surrounding medium. Hence the increment of time for each degree, in other words, the number of seconds occupied in reducing the temperature of the radiator 1 deg. (inserted in the last column of the table) should be proportional to the differential temperature inserted in the third column. For instance, the rate of cooling at a differential temperature of 49 deg. being 39.80 sec. for 1 deg., it should be $\frac{49 \times 39.80}{31} = 62.90$ sec. for an equal thermometric interval at a differential temperature of 31 deg. Referring to the table, it will be found that the rate thus computed agrees exactly with the increment of time inserted in the last column opposite the differential temperature 31 deg.

Applying a similar test to the other differential temperatures and rates of cooling contained in the table, the same exact agreement will be found to exist. Consequently, our table and diagram prove that the rate of cooling is proportional to the differential temperature, thus establishing the correctness of the Newtonian law. Regarding the discrepancy indicated by the slight irregularity of the curve *ab*, the writer attributes the same to the difference of emissive power of the radiator at different temperatures. It was stated in the preceding article (vol. v., pp. 505–507), that the radiant power of 1 sq. ft. of cast iron develops 0.080 thermal unit per minute for each degree of differential temperature at 65 deg., and 0.337 unit at 3,000 deg.; hence that the emissive power is increased $\frac{0.337}{0.080} = 4.21$ times for an increment of $3{,}000 - 65 = 2.935$ deg. Experiments conducted in the mean time show that the radiant power of 1 sq. ft. of cast iron maintained at a differential temperature of 1,800 deg. is 335 units per minute, hence that the emissive power at this stage of incandescence amounts to $\frac{335}{1{,}800} = 0.186$ unit for each degree of differential temperature. Our investigations have thus proved that at 65 deg. the emissive power is 0.080 thermal unit, at 1,800 deg., 0.186 unit, and at 3,000 deg., 0.337 for each degree of differential temperature. We have accordingly established the fact that the emissive power increases nearly in the same ratio as the intensities, being fully quadrupled between the differential temperature of 65 deg. and 3,000 deg. Let us be careful not to confound this increase of emissive power with the increase of radiant energy resulting from mere augmentation of temperature. It is, no doubt, owing to the change of the molecular constitution of the body during heating that the dynamic energy developed at a differential temperature of 3,000 deg. is 4.21 times greater than it should be in accordance with the Newtonian law—a trifling increase, however, compared with that resulting from adopting the computations of Dulong and Petit, whose formula shows that for the stated range of temperature the ratio of radiant energy will be increased more than 4,000 times. It would be premature to attempt to explain the cause of the change of the radiant properties of metals at different temperatures disclosed by our experiments, until further investigations shall have established the exact relation between the actual and theoretical energy developed. Considering the difference of molecular motion within metallic bodies at white heat, in a state of fusion, and at the freezing point of water, we need not be surprised at the variation of emissive power observed during our experimental investigation. Nor are we justified, in view of this variation of emissive power, in questioning the correctness of Sir Isaac Newton's assumption that heated bodies of definite radiant properties develop mechanical energies proportional to their excess of temperature over the surrounding media.

[It will be seen that the engraver has indicated, in Fig. 2, a continuous space between the curves *a b* and *a c*, whereas the space should cease at one portion, the curves intersecting each other between the ordinates 25 and 30. The mistake, however, is so trifling that it can scarcely be observed with the naked eye. It is to be found, on looking at the table, that the observed times are shorter than the calculated times at the high temperatures, while the observed times are longer than the calculated times at low temperatures; hence the curves must intersect each other.—Ed.]

Temperature of the radiating sphere.	Temperature of enclosure.	Differential Temperature.	Observed Time.	Corrected Time.	Increment of time for each degree.
Fahr. °	Fahr. °	Fahr. °	Seconds.	Seconds.	Seconds.
133	33	100	19.5	19.50	19.50
132	33	99	39	39.19	19.69
131	33	98	58	59.08	19.89
130	33	97	77	79.18	20.10
129	33	96	97	99.49	20.31
128	33	95	117	120.01	20.52
127	33	94	138	140.75	20.74
126	33	93	158	161.71	20.96
125	33	92	179	182.90	21.19
124	33	91	200	204.32	21.42
123	33	90	222	225.98	21.66
122	33	89	244	247.89	21 91
121	33	88	266	270.04	22.16
120	33	87	288	292.45	22.41
119	33	86	311	315.12	22.67
118	33	85	333	338.06	22.94
117	33	84	356	361.27	23.21
116	33	83	379	384.76	23.49
115	33	82	402	408.54	23.78
114	33	81	425	432.61	24.07
113	33	80	448	456.98	24.37
112	33	79	471	481.66	24.68
111	33	78	495	506.66	25.00
110	33	77	520	531.99	25.33
109	33	76	545	557.65	25.66
108	33	75	571	583.65	26.00
107	33	74	597	610.00	26 35
106	33	73	624	636.71	26.71
105	33	72	651	663.79	27.08
104	33	71	679	691.25	27.46
103	33	70	708	719.10	27.85
102	33	69	737	747.36	28.26
101	33	68	766	776.03	28.67
100	33	67	796	805.13	29.10
99	33	66	827	834.67	29.54
98	33	65	858	864.67	30.00
97	33	64	889	895.14	30.47
96	33	63	920	926.09	30.95
95	33	62	953	957.54	31.45
94	33	61	985	989.51	31.97
93	33	60	1017	1022.01	32.50
92	33	59	1050	1055.66	33.05
91	33	58	1084	1088.68	33.62
90	33	57	1118	1122.89	34.21
89	33	56	1152	1157.71	34.82
88	33	55	1188	1193.16	35.45
87	33	54	1220	1229.27	36.11
86	33	53	1257	1266.06	36.79
85	33	52	1294	1303.56	37.50
84	33	51	1331	1341.79	38.23
83	33	50	1371	1380.79	39.00
82	33	49	1408	1420.59	39.80
81	33	48	1448	1461.22	40.63
80	33	47	1489	1502.71	41.49
79	33	46	1530	1545.10	42.39
78	33	45	1572	1588 43	43.33
77	33	44	1615	1632.75	44.32
76	33	43	1659	1678.10	45.35
75	33	42	1704	1724 53	46 43
74	33	41	1751	1772.09	47.56
73	33	40	1802	1820.84	48.75
72	33	39	1852	1870.84	50.00

Temperature of the radiating sphere.	Temperature of enclosure.	Differential Temperature.	Observed Time.	Corrected Time.	Increment of time for each degree.
Fahr. °	Fahr. °	Fahr. °	Seconds.	Seconds.	Seconds.
71	33	38	1904	1922.16	51.32
70	33	37	1958	1974.86	52.70
69	33	36	2015	2029.02	54.16
68	33	35	2070	2084.73	55.71
67	33	34	2128	2142.08	57.35
66	33	33	2188	2201.17	59.09
65	33	32	2250	2262.11	60.94
64	33	31	2313	2325.01	62.90
63	33	30	2379	2390.01	65.00
62	33	29	2448	2457.25	67.24
61	33	28	2520	2526.89	69.64
60	33	27	2595	2599.11	72.22
59	33	26	2674	2674.11	75.00
58	33	25	2754	2752.11	78.00
57	33	24	2839	2833.36	81.25
56	33	23	2929	2918.14	84.78
55	33	22	3025	3006.78	88.64
54	33	21	3126	3099.64	92.86
53	33	20	3232	3197.14	97.50
52	33	19	3343	3299.77	102.63
51	33	18	3459	3408.10	108.33
50	33	17	3581	3522.80	114.70
49	33	16	3715	3644.67	121.87
48	33	15	3859	3774.67	130.00
47	33	14	4015	3913.95	139.28
46	33	13	4185	4063.95	150.00
45	33	12	4370	4226.45	162.50
44	33	11	4571	4398.73	177.28
43	33	10	4792	4593.73	195.00

NARROW GAUGE WOODEN RAILWAYS.

By H. HAUPT, C. E.

The undersigned proposes a system of narrow-gauge wooden railways, as feeders to trunk lines in rural districts and sparsely-settled localities, which can be constructed more cheaply than ordinary country roads and upon which transportation can be conducted at less expense than on ordinary railroads.

The system has been tested to a limited extent, and found to answer admirably. The construction—both of track and cars—is characterized by extraordinary economy and simplicity; it presents many novel features, and is applicable to all grades and to any locality.

TRACK.—The track consists solely of two parallel lines of timber, hewed on the upper and inside faces at right angles to each other; the other two sides may be left rounding or roughly hewed. No cross-ties whatever are used, except occasionally where the track is above ground, or crosses streams or ravines. The string-pieces themselves form the track, and they are laid in trenches and filled in, so that the top-surface is not more than a half-inch above the road-bed. The earth packed around them will effectually prevent spreading of the track in ordinary ground, but in soft places a few stout stakes may be driven outside. The joints are lapped and pinned. Streams are crossed by putting trestles or posts under the string-pieces, and the track is filled in with timber laid parallel to the rails, and covered with earth or gravel, for a horse-path.

Where saw-mills are convenient, sawed rails of hard wood may be pinned on the stringers, and renewed when worn out; but with a wide tread of 6 or 8 in., and wheels of wood, as is proposed, the wear of track will be very slight.

The road-bed may be narrow; the gauge of track not more than 3 ft., and curves of 200 ft. radius can be turned with facility. Turnouts will not in general be required, as the cars are so light that they can be run on or off the track with facility wherever the ground is level. The cars will generally be empty, or nearly so, in one direction, and the loaded cars would have right of way. Occasional turnouts will, however, be convenient.

Cars.—The cars are constructed without springs, and the wheels—which are the most important part—are made of hard wood, with a rim of cast iron for a flange, and treads of 6 or 8 in. to bear on the whole surface of the rail. The cost of a four-wheeled car would be about $30, and the weight about 800 lbs.

Cost of the System.—The grading in general will cost less than for a common road; and the writer has just finished four miles of graded wagon-road along side a hill, more than usually difficult of construction, at a cost of $125 per mile; the road-bed 9 ft. wide. The grading for a narrow-gauge wooden railroad should cost, in the locality of the writer in the mountains of Virginia, not more than $200 per mile; the hewing of the timber, $100 per mile, and laying, $75 more,—in all, from $300 to $400 per mile,—assuming timber and right of way to be furnished without charge; if not, the cost must be added.

It is assumed that few parties can be found owning lands through which such a road would pass who would not give the right of way freely, and also cut and drag to the line of the road all the timber required for stringers. Many, in addition, would cheerfully undertake to grade the road through their property, taking stock for their consideration. Under such circumstances, it is believed that $300 per mile will cover the cost of the railroad, if no rock excavation is required.

Influence of Grades.—On an ordinary railroad, as the Pennsylvania, with the rolling-stock there employed, the traction on a straight and level road is equivalent to 9 2-10ths lbs. per ton; and the angle of friction at which a car would move by gravity is 23 ft. to the mile.

The power required to move a ton on a straight and level wooden track can only be determined by experiment with the cars proposed to be used; but it will probably be safe to assume it at 16 lbs. to the ton of 2,000 lbs.; the angle of friction will then be 42 ft. to the mile,—on which grade the tractive power will be required to be doubled.

If a horse-power be estimated, as usual, at 33,000 lbs. raised one foot in a minute, it will be equivalent to the application of a tractive power of 187 lbs. moving at two miles per hour.

Assuming that an average horse will exert a power of 150 lbs. at a speed of two miles per hour, he would move 9.4 tons on a level, 4.7 tons on a grade of 42 ft. to the mile, 3.1 tons on a grade of 84 ft., 2.3 tons on a grade of 126 ft., 1.9 tons on a grade of 168 ft., and 1.6 tons on a grade of 210 ft.

The weight of the car would be about 700 lbs.; so that a horse could pull about a ton and a half on a grade of 168 ft.,—which grade is as high as will be found necessary under ordinary circumstances.

Cost of Transportation.—It has been found that one horse will haul 3,000 lbs., exclusive of weight of car, on a grade of 168 ft., and two horses consequently 6,700 lbs. A team of four horses on an ordinary country road in good condition can haul 3,000 lbs.

The cost of a pair of horses and driver is $2 per day—say $2.50; and on a road with undulating grades, the maximum not exceeding 168 ft. to the mile, twenty-five miles per day can readily be accomplished. The cost of carrying 6,700 lbs. twenty-five miles, exclusive of tolls, would therefore be $2.50, which is equivalent to ten cents per mile for the car and contents, or about three cents per ton per mile. Add one cent per ton per mile for tolls, and the charge would be four cents per ton per mile, to cover all expenses. As compared with wagon-transportation, the charge for twenty-five miles, with full loads, is usually fifty cents per 100 lbs., or $10 per ton—equivalent to forty cents per ton per mile, or ten times as much as the cost on the wooden railroad.

On Virginia railroads, for short distances of fifty miles or less, local freights are charged at rates of six to ten cents per ton per mile.

It appears, therefore, that the cost of transportation, including three cents per car per mile for tolls, would be less than on ordinary railroads, and only one-tenth the cost of wagon transportation on common roads.

If such a road should be fifty miles long, the cost of construction would be covered by $15,000 to $20,000; the cars would be owned by individuals. Two men, at $600 a year, would keep the road in good repair. To cover interest and repairs, would require only $1,500 per annum. At $1.50 toll per car, this would be covered by 1,000 cars a year, or three cars per day in both directions. It would be difficult, perhaps, to find a location so sparsely settled and so destitute of resources that within two years after the opening of the road less than five cars per day each way would pass over it, and this amount of business would pay a dividend of twenty per cent.

This calculation has been based on freight only, but passengers would be much more remunerative. For a distance of fifty miles the lowest rates would not be less than $5. But assume a charge of $4 to a passenger; ten passengers to a car for 100 days during the summer season, and five to a car each way for the balance of the year, and only one car per day each way, —the receipts from passengers would be $16,000. Deduct expenses of ten horses and drivers, $3,000, leaves $13,000, which, with the freight tolls, would pay not far from 100 per cent. dividends. Certainly there is margin enough in this calculation to allow the most liberal discount for contingencies and still leave no room to doubt that the investment would be profitable.

Operation.—Although empty, or partially loaded cars can be run off the track and replaced at almost any point with facility, yet it will be convenient to have passing places at intervals of half a mile. Passenger cars should have right of track, and, as they will run to schedule, there will be no difficulty in freight cars keeping out of the way. When freight cars meet, loaded cars should have right of way over those which are empty or partly loaded. When both are loaded, the one nearest to a siding should back. The cost of sidings is so trifling that they might be placed at shorter intervals if found desirable. The road could be used as a turnpike or public highway,—individuals putting on their own cars and teams and paying tolls. The Philadelphia and Columbia Railroad was operated in this way for some years after its construction.

Such a system of construction and operation of narrow-gauge wooden railways, with light cars and broad wooden wheels, combines so many advantages, so great economy, and such extreme simplicity, that it is believed, for the uses to which they are applicable, no other system can compare favorably with them, and their general introduction will no doubt be rapid in all localities where timber is abundant.

Locomotives with Rubber Tyres for Wooden Railways.—Traction engines for common roads with rubber tyres have been successfully introduced in Great Britain, and several of them are now being manufactured in the United States. These locomotives would appear to be peculiarly well adapted to wooden railroads such as are now prepared. The adhesion of rubber upon wood on a rail 8 in. broad would be greatly in excess of iron or steel upon iron, on ordinary railroads, and would greatly exceed the cylinder power as engines are now constructed, which is sufficient to slip the wheels on a dry rail.

The traction engines for ordinary roads weigh 6 tons, cost $5,000, and with the cylinders 6 by 10 in. haul 18 tons gross on inclinations of 1 in 30. Wooden railroads would require an engine specially adapted to their use; they should have four connected drivers, weigh about 6 tons, and run at a maximum speed for passengers of 12 to 15 miles per hour, and for freight 6 miles per hour. In the absence of direct experiment, it may safely be assumed that the adhesion of rubber on a broad wooden rail would not be less than 1-4th the weight, or 3,000 lbs., and at 6 miles per hour would develop a power of 60 horses, and with sufficient cylinder and boiler capacity should haul on a level 188 tons gross, on a grade of 174 ft. 44 tons, with a consumption of coal of 100 lbs. per mile, or one ton to 20 miles. At this rate the cost of motive power per ton of gross load per mile on a grade of 1 in 30 would be covered by about one-half a cent including engineer, fireman, fuel and repairs, while the proportion of paying to dead weight, instead of being 1 to 2 as on ordinary roads, would be probably 2 to 1, or four times as favorable, the cars when fully loaded carrying 3-4ths of the gross load of the train as paying freight.

Such a system would probably prove to be as far in advance of the ordinary narrow-gauge roads with iron rails in economy of construction and operation, as these are claimed to be superior to ordinary wide-gauge roads, and could be introduced even in poor and sparsely settled localities, to furnish an avenue to market for coal, iron, timber, or stone.

In the discussion of the merits of wooden railroads with intelligent practical men, some valuable suggestions have been made; one is, to apply such a road to canal propulsion. The wide wooden rails laid even with the surface of the tow path, the locomotive for towing provided with rubber tyres or with wooden wheels made in a peculiar manner, which would secure great strength. The track would not interfere with the use of the tow path by horses. An arrangement was also suggested by which flanges could be dispensed with on the drivers, and the engine run off or on the track at the pleasure of the engineer.

Wooden railroads have long been used for various purposes, but they have been constructed of light sawed rails pinned on cross ties. Such roads have not given satisfaction; they soon go to pieces under the action of iron wheels with narrow tread and heavy loads. The peculiarity of the plan now proposed consists in dispensing with cross ties, using a heavy stringer sunk in the ground nearly level with the road bed as the rail, a very wide surface of 6 or 8 in. for the rail, and an equally wide tread for the wheels. Such roads would be free from the defects of ordinary wooden railroads, and would be so cheaply constructed that no locality need be without a railroad. Their influence in promoting the settlement and development of a new country would be very great.

ON ARMOR-PLATED SHIPS.

By J. M. HYDE, Esq.

From the "Journal of the Society of Arts."

I need hardly say to the Society of Naval Architects that the subject of armor-plated ships for coast defence, or, indeed, for any other duty, is of the deepest importance at the present time. No one knows so well as those who have given any attention to naval construction, how difficult it has been to arrange a ship that shall contain all the requisites necessary for a ship of war, even under the old system; modern invention has given us material so vastly different to anything known to the men who fought our great naval actions in former days, that the entire system of actions will have to be changed when the next great fight takes place.

Your Society has thought fit to place the subject of armor-plated ships for coast defence the first on its list. The prominence so given proves that they esteem it a subject of deep interest, as well as one needing discussion and investigation, thus showing that at present there is some doubt as to what is the proper form of ship for coast defence. The contest between the guns and the armor plates has not ended, for so long as the guns progress in power so must the armor advance in strength; this is shown by the increase from 4 in., the first thickness of plates employed, to the present, 10 in. and 12 in., thus attempting to keep pace with the guns. Artillerymen will tell you, that, no matter how thick or complex the armor, if placed vertically they will be able to destroy it; no matter how thick the armor, it can be broken up by the modern shell. If this is conceded, if it is acknowledged that the guns can destroy the armor on a ship's side, then it seems to be desirable to examine if there is not some other system of construction that shall stop the guns in their victory. Much professional ability has been given to the arrangement of ships with low free-board, offering small resistance to the enemy's fire. Such ships admit of thicker plates being carried than those with high, lofty broadsides, and are, no doubt, with their turrets fitted on a breastwork, the most formidable of all the ships yet built; but still they are vulnerable, and, being so, are not of so much value as they should be. All vertical structure, both hull and breastwork, can be penetrated, and the question will very naturally be asked, Why not seek some other form of construction so that the men who may have to fight the future naval battles of England may have a chance of escape given them?

In offering for the consideration of your Society a different form of vessel from that hitherto adopted, I am quite aware of the very searching criticism that will be given to it; indeed, the importance of the subject demands that every possible investigation experience and experiment can bring should be brought to its careful study; and I am quite sure that the members of this institution will receive with attention any reasonable suggestion, even from so humble a per-

son as myself. Permit me, then, to say that, so for back as 1854, I began experiments with angular targets, quite believing even then that the guns would succeed in penetrating armor-plates. I am fortunate in having a letter still in my possession from the late Admiral Sir Byham Martin, referring to a proposition made and submitted to him for the construction of armor-plated gun-boats. I refer to it to show that this question of angular sides for ships has been of long continuous investigation, and I am not aware of any one having given earlier attention to it.

The difficulty and cost of constructing ships with vertical sides equal to resist the impact of modern projectiles is now generally acknowledged. It therefore becomes necessary to make some other arrangement, and, in the absence of a better, I am permitted to bring before this society my system of double deflection. The models and drawings now produced represent that system. In suggesting this form for a fighting-ship, I have kept in view all the essentials necessary. These are, first, stability and safety; second, invulnerability; third, light draught of water; fourth, comfort and accommodation for the crew. The first of these essentials, stability and safety, can be illustrated by the sectional models. These show sections of two vessels, one the ordinary ship of low free-board, the other a section of a double deflecting ship. Thee are arranged to be both of equal displacement, there being the same number of square inches in each midship section. An experiment with these models shows that in the first a given weight placed on the decks will capsize it; but the same weight placed on the deflecting model, in the same position, will have very little effect indeed, and even when placed on the outside of the deck will not have the same influence, thus proving the stability and safety of the one over the other. Actual experience thus shows the great advantage of an open-sided ship, especially its ability to carry heavy weights, such as turrets and guns, at a greater height than the ordinary vertical-sided ships. And as regards the invulnerability of deflecting ships, I am quite prepared to assert that no projectile can penetrate the hardened surface of a sloping or deflecting side. What I mean by the hardened surface is this, I do not propose to use the very soft material now employed in the manufacture of armor-plates, such as our present ships are plated with. Modern guns will send their projectiles through the thickest plate yet made; and, according to the highest authority, even 24 in. of iron will not resist the gun power that can be produced. If this is so, why not try the effect of a deflecting side to a ship, and give the plates a hard surface on the outside? Material can be produced, a sample of which I have here, that is soft on the one side and hard on the other. The effect of a shot upon the hard surface is like the blow of a hammer on the face of an anvil; it is the velocity of a projectile that makes it penetrate; and a hardened surface will deflect any projectile that strikes it with even the highest velocity at an angle. I therefore propose that the side of a fighting ship should be formed with an angle above and below the water-line, as is shown by the model on the table, and that the apex of the angle should be arranged to be some 3 ft. above the water-line; thus, such a ship would be difficult to hit fair, there being no face of the surface square to horizontal fire, neither at the sides nor ends. The decks and bottom must stand the same chances as in other ships; these will no doubt have to be made very much stronger than in our recent ships. The bottoms will have to be made to offer some resistance to the torpedoes, and instead of being only half-inch thick, I should submit 2 in. at least, and not less than 1 ft. of timber on the outside; in any case the bottom of all the future ships must be made, or at least they ought to be made, to offer a greater resistance to an explosion than the water in which they swim; this can only be proved by experiment; and in the present condition of this great question it would be a wise expenditure to construct a section of a ship, with say a 2-in. bottom and 1 ft. of timber, for the purpose of an experiment. We hear a good deal about ramming when the ships of the modern days are spoken of. Now, it occurs to me, that a deflecting ship, such as this model represents, would offer a good deal of resistance to that manœuvre; and I am inclined to think the apex of the angle of such a ship would do more injury to the ramming ship than she would receive from such an attack. There is also another advantage, and not the least in the arrangement of a fighting-ship, and that is the superior accommodation for the crew. Now, this is certainly a matter of very great importance, and however much ingenuity is expended in the design of a fighting-ship,

it should not be forgotten that the men who must fight the modern ships will be a much more valuable class, from the fact of the complexity of the machinery requiring a higher education, and therefore should be taken every possible care of. Now, a ship that requires artificial ventilation, like a coal mine, is not particularly agreeable as regards comfort for a closely packed crew, for should the machinery of the blowing arrangement get out of order during the excitement of a fight, the crew may stand a fair chance of suffocation for want of air. In the case of the deflecting ship, the deck being above the water-line, ample room is given for the crew, without the necessity of there being artificial means employed for obtaining the necessary air to breathe—in fact, all the essentials of a fighting-ship can be obtained by this system—invulnerability, steadiness of gun platform, easy draught of water, comfort for the crew, and moderate cost of construction. I produce samples of iron fired at vertically by a model gun, and also of tempered steel, fired at an angle of 22 deg., clearly showing the advantage of angular structures. I also produce samples of wood used to deflect the same projectiles. This also proves, that even timber when placed at so low an angle as 22 deg. to the line of fire, is capable of resisting a projectile of the more modern type. In submitting this particular form of ship for consideration, I am quite sure all who are interested in the success of the British navy will give me credit for a desire to maintain that power our common country has hitherto possessed, for, however brave our sailors, and however skilful the officers, our ships should certainly have every possible advantage that united ingenuity can give them, or the skill and bravery of those who handle them may be wasted in fruitless combat when the pinch comes.

EXPLOSIVE AGENTS APPLIED TO INDUSTRIAL PURPOSES.

By MR. F. A. ABEL, F. R. S.*

From "The Mechanics' Magazine."

The nature and properties of gunpowder, and its special advantages and defects as an explosive agent for industrial purposes, were first briefly reviewed. The application of chlorate of potash to the production of mixtures more violent than gunpowder was discussed, their general susceptibility to explosion by friction or blows was pointed out, and some comparatively safe compounds of this class, such as Horsley's powder and a substance called Tutonite, were specially noticed. The salts of an organic acid, called picric acid, now produced in large quantities by the action of nitric acid on the well-known antiseptic carbolic acid, were described as endowed with explosive properties, and as furnishing very powerful agents when mixed with chlorate of potash or saltpetre. Of these the "poudre picrate," or mixture of picrate of potash and chlorate of potash, was the most violent, but was far too dangerous, on account of the readiness with which it exploded by friction, to permit of its technical application. A mixture of picrate of ammonia and saltpetre, designated "picric powder" by the author, was described as certainly not more dangerous to manufacture and to use than gunpowder; considerable quantities had been produced with the ordinary appliances of gunpowder-works, and the material had received safe and successful employment as a violently explosive charge for shells.

Numerous other products of the action of nitric acid upon organic substances, endowed with explosive properties, were stated to exist, but only two of them—nitro-glycerine and gun-cotton—had hitherto received practical application, and these two constituted, at the present time, the chief rivals of gunpowder in many of its most important uses. Attempts were made to apply gun-cotton immediately after its discovery in 1846, and long before its properties were understood; but nitro-glycerine, which was discovered in 1847, had continued a chemical curiosity for sixteen years, its manufacture and application having been developed during the last nine years.

The early history of gun-cotton was briefly referred to, and it was shown that, even in the first days of its production and application, important results were arrived at, though the too hasty attempts to utilize it led to its speedy abandonment, as a highly dangerous material, by all but the Austrians.

* Inst. C. E., 14th May.

The improvements effected by Baron von Lenk in the application, as well as in the manufacture of gun-cotton, which first became public in 1863, led to a resumption of the employment of this agent in England, and to its careful study by a special Government Committee and others. The advantages of the Austrian gun-cotton, as a mining, quarrying, and engineering agent, were pointed out, as also the considerable improvements in point of power, economy, safety and convenience in use, in facility and uniformity of production, which had been effected by the reduction of gun-cotton fibre to a finely divided condition, and its subsequent conversion into highly compressed homogeneous masses. The rigidity of the charges of gun-cotton, and their consequent occasional tendency to become jammed in irregularly-shaped blast-holes, were, however, shown to be occasional sources of accident; and the necessity for strongly confining gun-cotton, in order to develop its full explosive force, was a defect which existed until recently, and had, for a time, rendered the material decidedly inferior to nitro-glycerine.

An account was next given of the successful manner in which Mr. Alfred Nobel had developed the practical condition of nitro-glycerine. His discovery, that the explosion of the liquid could be brought about through the agency of a detonation, and its successful manufacture, combined to furnish the industrial world with the most powerful explosive agent hitherto susceptible of application, and which agent, from its high specific gravity and insolubility in water, presented the special advantage that it could be used in positions whence water could not be excluded. The poisonous nature of the substance constituted an objectionable quality, and some uncertainty occasionally attended its employment, but its principal defects arose from the fact of its being a liquid, and from the comparatively high temperature at which it froze. The majority of the numerous fearful accidents which had occurred during the transport and handling of nitro-glycerine, appeared to be caused by the accidental leakage of the liquid from receptacles in which it was confined. The liability of such leakages to escape observation, and to lead to accidental explosions which would be transmitted to the confined nitro-glycerine, and the reckless manner in which the frozen nitro-glycerine had been frequently dealt with, in consequence of its apparently inert condition, had been fruitful sources of disaster, which had rendered the liquid, in its pure condition, a very unsafe material for employment as a mining agent. But Mr. Nobel had succeeded in applying nitro-glycerine in a simple manner, by which its defects, arising out of the liquid nature of the material, were remedied. He mixed nitro-glycerine with a porous and finely-divided silicious earth, and thus obtained a solid but plastic preparation, which could be conveniently handled and converted into charges of suitable dimensions, susceptible of application like any other solid explosive agent, and capable of detonation quite as readily as the pure nitro-glycerine. This mixture, called dynamite, and of which one or two varieties were prepared by Nobel, was stated to be one of the safest, most convenient, and most powerful blasting and mining agents. As now manufactured in the form of compressed charges, it retained as much as 75 per cent. of nitro-glycerine, without exhibiting any tendency to a separation of the liquid during transport and storage.

Several other nitro-glycerine preparations of more recent production were referred to, all of which might be regarded as modifications of dynamite. In some of them, such as Horsley's mining powder, dualine and glyoxiline, solid explosive compounds of mixtures were employed instead of porous silica as the absorbents of nitro-glycerine; in others, as in lithofracteur, the silicious earth and nitro-glycerine contained in dynamite were in part replaced by semi-explosive substances, for example by gunpowder constituents. None of these newer preparations contained so high a proportion of nitro-glycerine as dynamite, and although some of them, such as lithofracteur, might vie with it in regard to safety, it was scarcely possible that the substitution of other explosive substances for a proportion of nitro-glycerine in the mixture could result in the production of an equally powerful explosive agent.

When it was found, by recent experiments, that gun-cotton in the compressed form could be exploded by detonation like nitro-glycerine and its preparations, that substance proved to be quite analogous to them in its behavior, though the pure nitro-glycerine remained somewhat the strongest explosive agent. The suddenness of the explosion developed by detonation permitted of the application of compressed gun-cotton and nitro-glycerine to purposes

of destruction without any confinement, and thus operations could be expeditiously and effectually carried out with comparatively small quantities of these materials, which could only be accomplished by exorbitantly large charges of gunpowder. The rapid demolition of military works, bridges, etc., the breaking up of boulders, large masses of rock, guns, or castings or forgings, were quoted as operations of this class.

The author pointed out some of the causes of the great difficulty experienced in arriving at anything approaching a precise estimate of the relative power and effect of different explosive agents. Taking dynamite as the type of the practically useful nitroglycerine preparations, and as certainly one of the strongest, experience had shown it and compressed gun-cotton to be about on an equality in point of power, and to exhibit, in their most advantageous applications, a strength which was estimated at six times that of powder. The plastic nature of dynamite and its power of resisting penetration by moisture, gave it advantages over compressed gun-cotton, as it could be used in wet blast-holes, and as very irregular holes, or holes terminating in fissures, could be more conveniently and heavily charged with it than with gun-cotton. On the other hand, the readiness with which dynamite froze, and its inertness unless thawed, or fired by special arrangements, and the unpleasant effect experienced occasionally by those using it, were inconveniences not shared by gun-cotton. The advantages presented by these materials, in their general application as blasting agents, were shown to consist chiefly in saving of time and labor, especially in tunnelling or in blasting in hard rock. They were also susceptible of advantageous employment as auxiliaries to gunpowder, in the rapid removal of large masses of rock, or of submerged wrecks; the violent explosive agent being first used to produce extensive rending and shattering effects, and the superior displacing effect of powder being afterwards brought to bear. It was pointed out that gunpowder could not be satisfactorily replaced by these violent explosive agents in some kinds of work, where its comparatively gradual action was a specially valuable feature.

In conclusion, the author showed that, in the application of gunpowder to industrial purposes, some decided advance had lately been made, for its violent explosion could be developed, like that of all other explosive mixtures and compounds, through the agency of a detonation, whereby its action might be considerably intensified, and its application to some important classes of work, *e. g.*, in submarine operations, greatly facilitated.

CHARCOAL-USING BLAST FURNACES.

By G. FRASER.

From "The Engineer."

When lately considering the questions involved in the selection of sites for charcoal iron-works, the writer arrived at the conclusion that attempts at increase of production by undue concentration of the blast furnaces in any single locality represented a policy at once ruinous and suicidal; and he further endeavored to point out how important were the considerations which should be weighed in deciding whether the ore should go to the fuel or the fuel be taken to the ore. Apart, of course, from any special circumstances, either in regard to the position of the mineral deposits or the position of the forests with reference to them, his opinion was expressed to be in favor of taking the ore to the fuel, with the open alternative of both being brought together at some point relatively accessible to either. Having regard to the necessities of cheap means of transit and the primitive character of the countries to which, for reasons which he pointed out, charcoal iron-making operations are almost absolutely confined, the result of his considerations was, that the banks of rivers appeared to him to be in most cases the likeliest spots where suitable sites would be found, and for the positions of permanently placed furnaces; to that opinion he still distinctly adheres. There may be, however, and he conceives it is far from improbable, circumstances under which such sites might not only be unattainable, but even non-existent, and then would arise the question for decision, of how far, in view of the constantly shifting nature of the fuel supplies, it is good policy to adopt, for blast furnaces at

least, anything like a permanent location. That this is a somewhat novel view to take of the policy which should guide a charcoal pig iron manufacturer in his selection of the site for his works, will, the writer ventures to think, be very generally admitted, and perhaps until the idea be fairly grasped, the old associations which tend to make people look upon even a little wood-fuel blast furnace as something permanent and immovable, will have sufficient weight to give the proposal a chimerical appearance, which when duly considered in connection with modern means and appliances it does not really possess.

Perhaps the best way of approaching the question will be to consider what are actually the conditions of permanency which would seem to attach to a charcoal blast furnace, and what are those advantages which would accrue to it were its portability and that of the blowing engine a matter contemplated in their original design, and arranged for in the economy of their plan and construction. To begin with the furnace itself, the writer can see no difficulty—at least no insurmountable one—in having a framework formed in iron segments, to be bolted or screwed together in pieces sufficiently light to be easily transportable, even in countries where the roads or other means of transit may not be very good; and then the lining of this frame, at all events above the boshes, might readily be formed of any moderately refractory material, rammed in on a core in like manner as are made up the hearths of second melting cupolas. Indeed, whilst speaking of this, the writer may, perhaps, be permitted to say that, in his opinion, all small blast furnaces would possibly be found to last longer and withstand heat better were they constructed on the principle of simply ramming sound, seasoned, and well-tempered fire-clay between the outer walls or plates, and a solid core of the desired section. The experience and observation of all furnace and forge managers will, he feels convinced, bear him out in the statement he makes from his own, that in nine cases out of every ten the eating away of fire-bricks in furnaces commences at the point where either imperfect workmanship or the too liquid character of the clay grouting in which the bricks are set, leaves openings (possibly almost infinitesimally small ones, yet existing) for the flame in some positions, or the cinders and metal in others, to commence their attack. Attending, however, this proposed method of construction is clearly the absolute necessity of gradual and careful drying and preliminary firing.

Of the blowing engine, and the arrangements for getting steam, utilizing the gases, etc., it would probably be desirable, when defining primary principles, to go further into detail than is within the compass of such an article as is the present one; without, however, exceeding his space, it may, perhaps, be possible for the writer shortly to explain his views upon these points.

Taking it for granted that at but few, if any, of the charcoal furnaces in operation is the pressure of blast anything considerable, if at all over 2 lbs.; and assuming also that this pressure can be most easily and economically supplied by a short-stroke engine, with annular air valves and multitubular boilers, there surely can be no difficulty whatever in designing a machine which would not only provide the blast, but also be of sufficiently light and simple a construction to be readily and economically movable.

It must be remembered that, after all, these pigmy charcoal furnaces are, as has been said before, little greater in their air requirements than the larger cupolas now in use, and that, therefore, small light engines are fully equal to the task of furnishing the supply; and this being the case, there can clearly be no necessity for the heavy bedplates, huge framework, weighty cylinders, fly-wheels, etc., which the writer has seen placed in position for supplying blast to a furnace producing 35 tons of pig per week, and where the pressure at the single tuyere, blown through a 2½ nozzle, never exceeded 2 lbs.

To refer to the story of English iron factories, it seems sufficiently clear that our earliest producers of iron followed our great forests, and that when these ceased to exist the production of charcoal iron by necessity ceased. The writer does not, however, here in anywise mean to argue that mineral fuel iron did not, from its unlimited quantity and innate adaptability to the requirements of the age, necessarily supersede the charcoal qualities. Yet, nevertheless, if to countries possessing comparatively virgin forests, we can now take not merely the rude appliances with which our ancestors first won the metal from the ore, but machinery of the highest mechanical perfection, yet light, and fitted for easy re-

moval, it seems to the writer that there is a future before the enterprising manufacturer of charcoal iron who has the courage to bring to bear the science of the present day, on the, as yet, comparatively untouched natural resources of many of our colonies and other countries, not merely of great pecuniary success, but a future as a pioneer of civilization, worth, to some minds at least, vastly more.

GALVANIC ACTION ON IRON SHIPS.

From "The Engineer."

It was to be expected that the stranding of the Megæra—one of those untoward and costly accidents that stop little short of meriting the designation of calamities—should have caused attention to be directed more closely than heretofore to the conditions affecting the safety of iron ships. Not that there was any nine days' wonder attached to the break-down of that unfortunate vessel. She had long done good service, in the doing of which she wore out, and wore through—a very natural consummation, one, we may add, that had long been expected, one that needs no invocation of galvanic agencies to account for it, being perfectly explicable on the assumption that sea-water externally and bilge-water internally between them wrought out their full complement of erosion. Notwithstanding this opinion, we do not in the least undervalue the evidence elicited in the course of inquiry relative to the Megæra break-down. On the contrary, we think it highly desirable that the special action of bilge-water and the galvanic function of varied metallic contact in presence of bilge-water, should have been subjected to investigation. We believe that the evidence elicited drew the attention of many for the first time to a point that, amounting now to no more than a grave suspicion, may hereafter turn out to be a demonstrable fact, that the bottoms of iron ships incur more chances of erosion, degradation, and ultimate perforation from the effects of bilge-water, direct and indirect, acting from within, than sea-water acting from without. Under the category of bilge-water erosions, we comprehend not merely the direct agency of wash of the bilge-water itself, but the more fatal galvanic erosion set up when, unfortunately, bilge-water is recognizable as the chemical agent for developing galvanic action on a metallic couple of which iron is one and—as necessities of the case involve—the "sacrificial metal." It is an alarming fact in practice, and one that, being so perfectly in accordance with theory, ought to awaken no surprise, that should even a minute piece of copper come into contact, and so remain, with the inside bottom of an iron ship, then wetted with bilge-water, as, under the circumstances of the case, it necessarily must be, active galvanic energy is established between the two metals, and iron being the sacrificial metal of the couple, the bottom will, sooner or later—and sooner rather *than* later—be eaten through in a hole somewhat larger than the superimposed copper. A practical question now suggests itself, and it is this—to what extent, if any, would the erosive action be diminished by inclosing the piece of copper in a canvas envelope before depositing it on the interior of an iron ship's bottom as before? We ask this chiefly in reference to a circular which has just been issued, defining the duties and responsibilities of dockyard, steam reserve, and ships' officers, with reference to examining the inside of iron vessels. In these instructions it is enjoined that the bilge extremity of pipes must be of other material than copper or brass, and pipes of such metals as are of necessity in the bilge are ordered to be varnished and clothed with canvas. Stress is next laid on keeping the inside of the plating accessible for constant examination, and to the turn of the bilge covered with cement, but elsewhere painted or varnished—all these to be examined whenever the ship is in dock, and every part of the vessel below water is to be examined and reported on once a year. All these instructions refer to dockyard officials, but officers of commissioned vessels have duties of similar kind imposed upon them too. The chief engineer and carpenter are enjoined to examine once a quarter every accessible part of the skin and frames—making a report thereon, specifying defects, and also steps that may have been taken to remedy them. Outsides of all ships are to be examined annually; gun-metal propellers must be coated with cement and fitted with zinc protectors.

A PLEA FOR GOTHIC ARCHITECTURE.

From "The Lambeth Review."

Let us now proceed to examine what there is in the nature of Gothic art which enables us so very confidently to prefer it to any other. And here we may say that we should be the last to ignore at all the claims which Gothic architecture has upon our love and reverence by reason of its connection with all that is most interesting in the history, the romance, and the religion of our country; whilst at the same time we are quite prepared to maintain its claim to be up to this time our only national and indigenous form of architecture. These would be strong grounds indeed for loving any form of art; but they are not the grounds on which at present we desire to insist on the truth of our views. They are rather reasons founded on tender sentiment than on practical considerations, and architecture is so essentially a practical art that we prefer to put forward none but practical arguments in favor of the style on which, as we believe, our architects ought to found the whole of their future work.

The arguments for the use of the Gothic style in buildings of every description are, then, mainly these—that it is a practical, a real, and, in this country, a natural as well as a national style, and above all, eminently a free style of architecture; suited, therefore, to deal in the best way with the many new problems of construction and materials which have to be solved by every architect in these days. These are the arguments for Gothic architecture which have often been put forth and have never been seriously controverted, and which, indeed, admit so little of either a denial or an answer, that one cannot affect to wonder at the course pursued by objectors, who, ignoring altogether their very existence, devote themselves instead to meeting the other arguments for it, which appeal indeed to the sentiments and instincts of very many of us with the greatest possible force, but which are still not the real foundations on which we ground the whole superstructure of our belief.

The reality and truthfulness which characterize all good Gothic art are, then, its real claims on our respect, and unless architects always remember this in their work, they will find no difficulty whatever in sinking as low as any of their predecessors.

If we examine the ancient examples of domestic architecture still remaining in every part of our country, we shall find that they are almost invariably designed and constructed on the simplest and most utilitarian system. Their ground plans were arranged, not in order to secure an academical uniformity on the exterior, nor without reference to the undulations of the ground on which they stood, but so as exactly to suit the wants of the building and of the locality. The facility, indeed, with which a mediæval architect suited his work to its position, is marvellous. His building seems to grow out of the ground on which it stands naturally and vigorously, and requires no artificially-made mounds of unnecessary earthwork, painfully precise in their heavy outlines, to serve as sham foundations for its walls. The arrangements of an old building, where they mark customs or wants which have died out, are not such as any one need slavishly imitate. But the principle of the arrangements was one which we should all do well to follow. Rooms were not packed together within a square box-like outline, and lighted, whatever their size or insignificance, by windows of the same shape and importance; but the use of each room was appropriately marked by the character of its decorations, and (to take one example out of many), instead of designing chapels and infirmaries of great institutions so absolutely identical in appearance as not to be distinguishable one from the other (as we have seen done lately), the use of almost every part of a building was marked even on the exterior; if there was a chapel, it was conspicuously a chapel; if a hall, the guests and retainers had no difficulty in seeing afar off where they should find it. If a house was to be built for defence, Carnarvon and a hundred castles elsewhere may tell how naturally it was done. If for study and seclusion, what can be more practical than such colleges as those of Winchester, Oxford, and Cambridge, or more perfectly adapted for their purpose than the great institutions of the religious orders which are still the jewels that adorn the fairest spots throughout our land?

The internal arrangements to suit the convenience of the occupiers were as natu-

ral and often consequently as picturesque as those arrangements of the exterior which were devised to suit the locality—and we can never do better than follow their example in this respect. Nothing is so wearisome as the dreary similarity of the plans of modern houses; you do not want to be able to settle before you enter exactly the number of rooms and position of every one of them in a house. If there be a surprise of any kind in some unexpected arrangement in a new position of a staircase, in a room lighted by windows a little out of the common in their place or shape, or with some pleasant recess where you can escape from the usual four-square simplicity, how grateful do you not feel to the designer? You feel directly that you are in the presence of work done by a man who has thought about putting some of his own mind into it, and of giving it some human interest; he must have conceived of his room furnished and inhabited; he knew that a quiet bookish corner might be made here; that there, in the cheerful recess of the bay window, a merry family group might assemble; that on the wall here the best work of art the house possessed might be fitly enshrined in its frame; whilst there the eye would be satisfied with the diaper grave or gay on the tapestry or hanging with which the walls are covered. In the hall one would like to find recesses where they were wanted; a staircase shut off with screens glazed or open, and charming the eye by the intricate framing of its natural and artistically-treated carpentry, and, in short, everywhere the beauty that always attends natural dispositions of the plan, and poetical conceptions of life and its arrangements. Who is there that has not felt all this? Who is there that has not occasionally thought that the house even of a hundred years since, often somewhat irregular in its plan, in its levels, and in the general design of the interior, is, after all, infinitely more delightful than the pretentiously regular houses in which most of us are now compelled to pass the whole of our lives, without the remotest possibility of ever feeling any love for any one of the rooms or any part of one of the rooms they contain? This is a miserable state of things; the object ought to be to give each man something to love in his own house and in his own room, and the more specialty of character, the more peculiarity and quaintness, the more beauty, and the more soul there is in the design and arrangement of the interior of a house, the more chance there is of this.

Our old Gothic architects accomplished all this; their love of variety and the rationality of their treatment of all details made this possible, whilst they saved them also from the dreary monotony of that iron law of uniformity which has impressed itself upon architects just in proportion as they have succeeded by their rules, their traditions, and their fixed systems in destroying all special character in the individual man, and making him little more and little better than a machine. They never thought it necessary to sacrifice common sense to symmetry, so as to make, for instance, every window absolutely alike throughout a building hundreds of feet in length, without reference to whether they light the principal apartments of the house, the butler's pantry, the staircase, or the *garderobe*. They built no enormous porticoes leading only to the first floor rooms, and therefore seldom used, or if used at all, conveying the idea—as we see at the National Gallery—that the rooms on the ground floor are mere cellars; and so unfitted to our climate, that—as we see at the British Museum, or as we used to see too, during the season, at the Royal Academy—they are obliged to extemporize a glass or canvas cloister within the portico in order to enable the public to pass through it.

A happy result of the course which our forefathers pursued was that their buildings were, perhaps, the most picturesque in their grouping and general effect that were ever seen; and there are few Englishmen, fond of the scenery of their country, who are not ready to admit the singular fitness of the buildings for their sites which marks mediæval houses in contrast with most of those of any pretension erected within the last two centuries.

This picturesqueness is so natural to our English eyes that even in later days a long array of buildings may be adduced, arranged in imitation of Gothic houses, with almost exclusive attention to picturesque effect; whilst, in some districts, the Gothic principle may almost be said never to have died out. Elizabethan and Jacobæan buildings were the obvious result of a struggle to retain the loved and lovable characteristics of earlier works; and there are large districts in which, as in Northamptonshire and Somersetshire, the steep-roofed, stone-monialed

houses, and others—as Sussex or Kent—where even the farm-houses and cottages were instinct with the old fire, and scarcely touched by the influence of the classic school, even down to the end of the last century—the country builders never having given up their old traditions, and modern architectural rules and mannerisms having never been introduced among them.

Is it possible, then, to adduce better reasons for any kind of architecture in the world than can be adduced for our own Gothic style? It is the style consecrated to us by its essentially national character, as proved by its development through all its stages in our own country; consecrated also by its essentially religious character, as shown by its use in all our religious buildings, and its connection with all our most sacred associations; allied with all our best types of education in our great universities and public schools; with all our ideals of the picturesque and the homely in countless old houses spread across the land; and with all our recollections of charitable duties in the hospitals and bede-houses, of which so many still remain. It is a utilitarian style, and a free and practical style, as is proved by the way in which, of old, it availed itself of every obtainable material, every then conceivable resource, for the development of its character and the increase of its attractions. A style, therefore, which if it be treated in the same spirit and with the same sense of the real duty of the artist as of old, must lead modern architects to combine, with a healthy reverence for the past, a hearty energy in availing themselves of all the many advantages and opportunities of the present; a style in which it is no task work to design, in which there is no sense of bondage, but rather the noblest kind of freedom—an ordered liberty.

It may be said, however, as it often has been, that these developments which some men think so natural and so lawful, will really destroy the Gothic character of our work. It must be observed, in passing, that this assertion is not always very honestly made, because generally those who make it are the very men who venture themselves on far greater departures from the Renaissance or classic types. But it is, however, sometimes used by those who are, or pretend to be, in favor of Gothic, and to them a few words are due. They have a just dread lest any one should merely import copies of foreign examples—not understanding how to gather the lessons which they teach, and so as to obliterate all the distinctive character of English Gothic—and to a great extent we are inclined to agree with them. We do not sympathize with those who would plant Venetian palaces among the trees and in the parks of England; though, on the other hand, we have as little sympathy with those who refuse to learn any lesson from buildings which contain so much that is alike beautiful and useful.

The Italians, for instance, to whose work the greatest objection is usually made, were for a long period but little behind French, Germans, or English in love for Gothic art. Theirs was a land of redundant richness in art, and, if the Etruscan and Roman remains are noble and numerous, those of the Gothic period are no less so. There is, moreover, this special feature about them—that they are almost as well suited in every respect for modern use as any buildings can be. The Italian towns in the middle ages were much like our own at this day; they were great centres of general intelligence and of artistic pursuits. The houses inclosed within their walls were often true palaces—light, airy, and cheerful—imposing in their character, and in no wise savage or gloomy. The vast number of the mediæval remains in Italy is most remarkable, nor less so is the enthusiasm with which every one with the eye and hand of an artist singles them out at once as the subject for every sketch or painting that he makes. Their value to us will be seen if we examine them fairly and without prejudice. If the necessities of locality require brick building, nowhere in Europe shall we find more suggestive examples than these. If covered passages are wanted, nowhere can we see more perfect types than are afforded by Italian examples of their treatment. If decoration in marble or with color be an object, the best examples of both are to be seen in Italy. If the value of ground be so great that we are obliged to use it economically with simple unbroken masses of wall and great height of elevation, nowhere else are both so often seen as there. Besides all which, it is not difficult to trace analogies and similarities between many features in English and Italian Gothic. Our architecture is all derived from Romanesque or Byzantine work, and despite the alterations and modifications which were gradually made in it, still bears evidence of

its origin; and, in availing ourselves of hints and suggestions derived from the study of foreign examples, if we begin with sufficient reverence for and knowledge of our national art, we may avail ourselves of the lessons they teach without showing any want of loyalty to our own traditions.

Take the case of windows, for instance, and it is impossible to say that there is anything opposed to our English Gothic in the best Italian examples. We are told that the windows of some of our oldest buildings are too small, inconvenient in their construction, and only fitted for the most primitive mode of glazing. Now, whatever modicum of truth there may be in this charge as applied to ordinary English windows, there is none whatever if it is applied to Italian examples. They are either wide single lights with simply pointed or cusped heads, or they are grand compositions of several lights divided by detached shafts, and surmounted not unfrequently with fine open traceries. The principle of all is alike. They are ample in their width, and the window frames of wood are placed behind the stone jambs or shafts. They admit, therefore, of any kind of wooden framework for sashes, French casements, or shutters; and where they are used it is a matter of perfect indifference what fashioned fittings it is desired to introduce, whilst it seems preposterous to suppose that those who inherit the traditions of the only school of artists who ever treated the decoration of glass in a right manner should be debarred from adopting any kind of glazing the use of which is demanded by reason of the advantages which it affords. There is no one, probably, who really believes that if plate-glass had been made in the 13th century, architects would then have refused it admission into their buildings; and, though one may more than doubt the artistic advantage of introducing it, it is simply absurd to say that it is unusable. The advantages which it presents are many and notorious; and, on the other hand, the disadvantages of its use, if not so obvious, are still serious. Seen from the exterior, its broad, smooth surface makes the windows look like so many unglazed holes in the wall, and there is none of that play of light and shade and color which in other glazing pleases the well-trained eye; whilst seen from the inside its effect is always cold and cheerless. Doubtless the most pleasing glazing is always that which shows some kind of design and taste in its arrangement, and it is quite possible to combine this with larger unbroken space in those (generally the lower) parts of windows which are alone used for looking out of. The subdivision of the rays of light is always, by very much, more agreeable to the eye than their admission into one unbroken mass; and, however much the smartness of plate-glass commends itself to modern taste, every one who goes into an old house, which still retains its old glazing, is involuntarily charmed with its effect.

The system of design of Italian windows is not unknown in England. In the 12th and 13th centuries most of our domestic windows had shafts instead of moulded monials. Examples may be seen at Southampton; at Christ Church, Hants; John of Gaunt's House, Lincoln; Boothby Pagnel; Longthorpe; Oakham, and many other houses of that age. If we cross to France we shall find examples of the same kind occurring constantly. In Belgium we shall see them in the best early works—as *e. g.*, in the exquisite town hall at Alost, and in Germany, in the numerous mediæval houses of Ratisbon—to mention some of the oldest out of numerous examples.

It will be seen, therefore, that we have not to depart from English or northern traditions in adopting more largely a type of window which happens to have been brought to the greatest perfection and used most frequently in Italy.

It is difficult to over-estimate the peculiar advantages derivable from the Gothic treatment of windows. It need hardly be said that, if there is one feature of detail which marks the style more than another, it is the system of fenestration. To add windows to classic buildings you either rudely run counter to all old traditions, or you are obliged to treat your windows with very little variety, and generally just in the same way, and with the same details, as your doors. In classic buildings the window is an inconvenience, in Gothic it is the principal ornament of design. The consequences of this difference are important and notorious. In a Gothic building the windows may be proportioned exactly to the wants of the room they light; every variety of size is admissible. They may be wide or narrow, tall or short, divided by monials or not; for, if a wide opening is admissible in buildings which do not freely allow the introduction of arches, surely it is tenfold

more so in one which insists upon the arch, and objects to the invariable cracked window-head of our 19th-century houses. The openings of windows may be square-headed, cusped, or simply arched; square-headed windows are of constant occurrence in early work. Sometimes the openings are wide, and have flat segmental arched heads; often the openings are square-headed, but above them are pierced traceries. They may be contrived also to suit exceptional positions. In staircases, for example, they may be built with sills sloping or stepped to suit the rise of the stairs. They may be projected or corbelled out, as bay windows or oriels, and they may have balconies, which will be best liked when they are most closely founded upon the Venetian examples, whose simplicity, beauty and utility make it impossible to devise any form which shall be an improvement upon them. They may be placed so as to command particular views, at an angle of a room or wherever most convenient, or they may be placed as close together as is necessary to secure the very largest amount of light in the interior. Finally the absence of all necessity for a rigid uniformity of the exterior makes it easy to introduce them wherever most wanted for internal convenience, whilst the flexibility of the style makes it possible not unfrequently to make every window tell its own tale, just as we see in old houses, where the chapel, the hall, the lady's bower, and the kitchen, are each so clearly marked that even in their present most forlorn state they can be still recognized with the greatest ease. Comparing the liberty of Gothic work with the bondage of classic and Renaissance in this respect, we may well be astounded at the infatuation which can make any one doubt as to the superior fitness of the one to the other for modern use. In the latter styles all the efforts of centuries have left but two or three types of windows for our choice—the one a mere square hole in the wall, another the same hole adorned with a shallow ineffective moulding, and the third the same with the addition of a pediment, sometimes straight-sided, sometimes curved, and sometimes by special inspiration broken in two in the centre!

Sad will it be if in so-called Gothic buildings these traditions are allowed to interfere with the whole spirit of the style! Yet that this fear is not groundless is proved by the designs for some large buildings which we have seen, in which, in spite of a few Gothic mouldings and a good many pointed arches, all life has been sacrificed to a desire for uniformity.

From windows let us turn to doors, and we shall again find a variety of examples affording us the greatest liberty it is possible to conceive. The opening may be arched or it may be square, and its proportions may be varied in any way. Our doors may be hung with hinges of brass or of iron, as simple as our poverty requires, or as full of cunning handicraft as the best smith we can find can make them. Our external doors may be protected by porches, by cloisters, by covered ways, or, if we want none of these protections from the rigor of our climate, then by delicate overhanging canopies of wood or of metal, and they will still not depart from the strictest limits of ancient precedent.

The inside finishings and fittings of a house may all be similarly devised, either in accordance with those of old buildings or on a principle of design entirely in harmony with them.

Ceilings may either be open, showing the timbers, or boarded and panelled on the under side, or plastered and stamped, or painted with diapers, or of iron filled in with terra-cotta or brick, the only liberty not allowable being indulgence in the fashionable plaster cornice and unsafe plaster ornaments of our modern houses, the object of which is not quite intelligible, whilst the structure is invariably false and not unfrequently dangerous. If we must have Gothic cornices they ought either to be of stone or of wood; in the former case giving additional support to the floors, in the latter being usually the moulded edges of the plates below the joists.

Plaster may legitimately be ornamented with diapers in the manner common in England in the seventeenth century, or cut into patterns in the way we see in some of the best Moorish work in Spain; but its use as an imitation of stonework is no more defensible inside our houses than it is outside. In both it is equally false in principle, and in both equally bad in effect. For other internal works the subtle delicacies of the carpenters' work of the middle ages suggest and admit of endless development. The truthful treatment of material which characterizes it will be, above all things, advantageous, whilst the suggestive character of some of the Italian works will show

us how easily we may, if we will, introduce every kind of inlaid work in various colored woods in furniture, floors, panelling of walls, doors, ceilings, and staircases. Our ancestors used oak because it was always readiest to their hands; we have no such facility now; and, if we are obliged to go abroad for our woods, we shall be wise to put all descriptions of wood under contribution, and to use them as we may be sure our ancestors would have done in our place. They varied their material in every possible way. Sometimes for instance, they covered their doors with rich colored leather, at other times painted them, and if they had possessed our facilities they would have inlaid them also. So that, as compared with the revivers of Classic art, those who follow Mediæval precedents really enjoy great liberty in the treatment of the mouldings, carvings, and general details of their work, which may all be significant and illustrative, and not eternal reproduction of the same forms.

We have shown sufficiently, we think, that the cause we advocate demands no sacrifice whatever of convenience or of reality, that it is easily adapted to our wants, and that one of the chief grounds on which we adopt it is, indeed, the perfect freedom which it affords for doing good work in every kind of material, and for every possible use; and, if this be so, there can be no pretence whatever for saying that there is any less reason for adopting it for houses and public buildings than for the churches, in which all the world allows that it has been of late years applied with no small amount of success.

Let us now consider as briefly as possible how we should meet the problems which in these days ordinarily present themselves to us in matters affecting, not the design of a single house, but the arrangement of groups of houses in cities, or the laying out of entirely new towns. How, for instance, are we to devise great public improvements in towns? Are we to follow the example recently set us in Paris, or are we to found our work rather upon an earlier and different system? The Parisian system excites, we confess, our strongest antipathy. We can see no beauty, no real dignity, no nobility in the eternal sameness of such streets as the Rue de Rivoli, or most of the new Parisian streets and boulevards, nor in the idea which they represent, that every row of houses must be perfectly regular and uniform in its scheme, that every square or *place* must be uniform on all its sides, and that every street must be arranged as far as possible at right angles to its neighbors.

This is not a Gothic system, because it is not a natural system, nor is it a Greek system or a Roman system, but simply the latest development of the poorest kind of Renaissance art.

All good architecture has been natural in its growth, and a street which tells its own history is always picturesque, whilst a new street, made to order like Regent street, Moorgate street, or the new boulevards and streets in Paris, is invariably tame and uninteresting to a degree. We do not forget the examples of mediæval towns built on a regular plan, such as Winchelsea, Carnarvon, or the Bastides in the south-west of France. But these were exceptional cases of towns planned all at once, and irregularity in their case would have been unreal and mistaken. Even in these cases, however, it was only the arrangement of the streets that was regular; the buildings which lined their sides were as distinct in their individual character there as elsewhere. If we compare the examples of modern streets built on the two systems, we cannot doubt for an instant which is to be preferred. Take, for instance, Gower street or Harley street, where the dull monotony of the houses makes it certain that were it not for the numbers painted on the doors their very owners would be as likely as not to get into the wrong house; and such streets as Brook street, or Grosvenor street, where every one has built his house to please himself, and consequently with a comparatively good general effect, bald as the designs of the several houses are in themselves.

In a square or *place*, again, unless the buildings are all for some perfectly similar purpose, there is no reason for absolute uniformity. Some defenders of Gothic, it is true, have maintained that it admits of as much uniformity as Classic, and quasi-Gothic designs have been made which are as senselessly regular and balanced in their plans as any of the Renaissance works of which we complain. But with all deference to their authors, theirs is an entirely erroneous mode of design. The Cloth Hall at Ypres, which is often quoted as a regular and uniform Gothic building, was made so to a certain extent (for it is *most* irregular in its general plan, owing to the shape of its site) solely because its arrangement and uses

within were absolutely uniform. The Ducal Palace at Venice was similarly circumstanced, as were all really fine buildings of the mediæval period which are regular in their scheme; and we know of no example of a square or *place* in which anything has been gained by the uniformity of buildings erected for different purposes on its various sides.

Take the Piazza at Florence, and observe how everything is gained by the irregularity of the various buildings which surround it, each telling its own tale. Would the Piazza at Perugia be improved by making the magnificent Palazzo Publico a perfectly regular erection, or by the re-erection of the Pisano fountain just in the centre, and pulling down the Cathedral in order to erect another palace uniform with its neighbors in its place? So, too, at Venice; is not the irregularity of the Church of St. Mark and the one-sided position of its Campanile the very making of the Piazza, without which the whole would be tame and poor in its effect? The best Renaissance street, probably, in Europe is the Strada Nuova at Genoa; this is narrow, irregular, and amazingly picturesque. Each of its palaces has some individual purpose and character, and its course is not straight. Out of Italy, all our large central spaces are comparatively irregular. Even in London, so natural and gradual has been our growth, that most of our public places are fortunately somewhat irregular, and therefore natural in their shape. The finest view in London, as every one knows, used to be that from the bottom of Ludgate-hill, with the winding irregular acclivity and the dark outline of a spire half way up, cutting across the west front of St. Paul's in the most natural and effective manner. And if we leave Sir Christopher Wren's work, and, going westward, stand at the upper side of Trafalgar square, we may well ask whether we should gain anything by a fourth side, square and uniform with the others, in place of the picturesque sweep which now leads the eye down to the Gothic group of steeples and spires which marks Sir Charles Barry's great work at Westminster—work on which, in spite of cavillers, the World will always look with admiration and interest, and which is undoubtedly the greatest architectural group of which London can boast.

One of the best streets in England is the High street at Oxford; yet it varies in width, is on a curve, and is entirely irregular in the arrangement of all its architectural attractions. On the other hand, the latest attempt on a large scale on the Parisian model is to be seen at Cologne, where they have bridged the Rhine exactly to the east of the Cathedral, leaving it the centre of a great *Place*, and anything more lamentable in its effect, and yet more obviously the result of a painful effort, can scarcely be conceived.

In truth, all these examples are evidences of the charm of natural irregularity, even in the most important and central positions of great cities; and they lead to the observation that in grouping of public, just as much as in the arrangement of private, buildings, in ninety-nine cases out of a hundred it will be most inconvenient to attempt any great degree of uniformity. So an arrangement which brings out the individual uses and peculiarities of each house in a street, as far as possible, is surely much better than the modern system of driving herds of people into a succession of similar houses, as though they were so many machines incapable of separate or original wishes or actions, and properly dealt with, as one is nowadays in a great hotel, by being ticketed and numbered till almost all sense of personal identity is lost.

In a large public building the same argument is soundly applied. If the arrangement of the interior allows of perfect regularity without inconvenience or effort, and with due regard to the propriety of letting every part tell its use by its decorations and design, there is no objection whatever to uniformity. The nave of a Gothic cathedral is evidence that there is nothing in such uniformity contrary to the Gothic spirit; but directly these conditions are not observed, uniformity is a crime, and the very men who built the regular cathedral nave have surrounded it with a group of subordinate buildings, the Chapter House, the Cloister, the Refectory, the Dormitory, the Bishop's Palace, the Vicar's Close, the gateways, and the enclosing walls, each one of which was designed with absolute freedom from the bonds of regularity, and with a sole eye to usefulness and appropriateness. It is notorious that when a regular outline is adopted for a building, it seldom happens that the internal arrangements allow properly of all the windows and doors being equidistant, and of equal size. True and reasonable uniformity consists in making the main lines of a building, the cornices,

the string courses, the roof lines, the general detail of the windows, harmonize, without doubting for an instant about the power of breaking this uniformity, wherever it is possible by so doing to give emphasis to the more important, or to withdraw attention from the less important, portions of a building. If a public office is to be built for 500 clerks, all equally insignificant, by all means let us put them into a barrack which tells nothing about them to any one; but if it is to contain a Secretary of State, Assistant Secretaries of State, grand staircases, inferior staircases, grand public entrances, and small private doors, by all means let us follow the old example, and show as many as possible of these facts clearly on its face. Unless it does so it is a huge sham; and, whether its detail is Gothic or not, the result must be bad, because unreal, and not instinct with any true artistic spirit. This protest against the attempt which is now sometimes made to disarm the hostility of the Renaissance school, by adopting the worst feature of their mode of design, appears to be very necessary, and we are the more disposed to make it, because it cannot be doubted that the true solution of the hostility which has been shown in some quarters to the designs for the largest building of this day—the New Courts of Justice—is almost entirely, if not altogether, due to the determination which has been shown to carry out the real principles of Gothic building as distinguished from Renaissance throughout the design. Sir Charles Barry, naturally enough—looking to his education and his taste for Italian architecture—designed an Italian building for the Houses of Parliament, and clothed it everywhere with Gothic detail. The only way in which his design has been saved from failure and tameness, is by the happy inspiration which led him to the picturesque grouping of the towers and turrets, which, when seen from the Thames Embankment, or Trafalgar square, compose as beautifully as can be desired; and we know not where it would be possible to point out a happier example of one of the great gains in such cities as our own from the adoption of Gothic architecture than in the variety and beauty of their general effect, owing to the infinite variety of sky-line, for which they always afford opportunities. A late President of the Institute of Architects, and distinguished architectural student—Mr. Beresford Hope—has often and at much length descanted on this subject; and it is sufficient for our purpose to point out how very much such an outline as that of the Houses of Parliament effects for the general aspect of London, when compared with our other public buildings in the classic or Renaissance style, such, *e. g.*, as the Post Office, the British Museum, the National Gallery, or Somerset House, whose only effect is one to be seen from the very streets themselves in which they are erected.

After the Houses of Parliament, the next great opportunity of a public building was the proposal to erect the Foreign and War Offices. Lord Palmerston's ignorant prejudice against all Gothic buildings—indulged the more vehemently, because at the moment all substantial power in matters of State was slipping out of his hands—prevented the carrying out of Mr. Scott's design for this building. This was a very real subject of complaint and regret, in spite of the feeling entertained by some that the design was conceived to some extent upon the principles which Barry had adopted in the Houses of Parliament, though wrought out with Mr. Scott's usual fertility of invention and taste.

The Courts of Justice are the third great opportunity, and we rejoice that all the competing architects gave in their adhesion to Gothic as the only practical style in making their designs, and that the opportunity is afforded of acting in the construction of the building on the principles on which alone, as we have shown, all good Gothic buildings in all times have been designed. The component parts of such a building are not very many, but they are diverse. There is of necessity a collection of Courts of Justice round a Central Hall; there is of necessity a vast number of rooms of varying importance for Judges, officers of the courts, and mere clerks. Finally, there is a broad distinction between Courts properly so called, and their belongings, and the legal offices. If the principles which we have attempted to lay down have any truth whatever, then undoubtedly all these varying rooms and chambers ought, as far as possible, to be distinctly and intelligibly treated and differenced in the actual building. And it is, as we believe, because this has been attempted in the design, because in so doing popular traditions and modern customs have been rudely opposed, that the architect and his design have been so heartily attacked by some of his brother architects.

THE EFFECT OF TORPEDOES ON NAVAL CONSTRUCTION.

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The only submarine attacks upon vessels which are as yet known to be effective, are those of the ram and the torpedo. Submarine gunnery has not yet attained a practical form, except in the restricted shape of plunging fire from flat-headed projectiles. The object of the present paper has almost exclusive reference to torpedo attack.

I may state at the outset, that no vessel can receive with impunity the effective application of a torpedo of very large size. The work of destroying the floating capacity of a ship is out of all proportion small as compared with the work which it is possible to store in a submarine explosive of large size; and provided always that this stored work can be applied with certainty and efficiency, there is no alternative to the destruction of the vessel.

Nevertheless torpedoes must be encountered, and our task is to ascertain the conditions under which we are likely to encounter them, and what expedients we must adopt in order to receive the smallest possible amount of damage from their destructive power.

Hasty conclusions have been stated, to the effect that, since armor-plated sides are no protection against an explosion taking place under a ship's bottom, therefore armor-plating must either be abandoned altogether, or extended to the bottom of ships. Either alternative is fallacious. We will deal with the second later. With reference to the first, that armor-plating must be abandoned, it is sufficient to consider what the ordinary use of torpedoes must be, to see the error which underlies it. For torpedoes used by ships at sea, the armor-plated ship will always have the same advantage as it has without the torpedo, in being able to receive with impunity the cannonade from its adversary. An unarmored ship might certainly render pursuit difficult by dropping torpedoes in her wake; but she could not venture to attack an armored and strongly-armed ship by means of movable torpedoes—for she would be destroyed by the fire of her enemy, if she ventured within any reasonable range for the use of her torpedo attack. I do not say this mode of attack is an efficient one; but simply that the armor-plated ship has the same preponderance of efficiency with the torpedoes as without them.

If the torpedo be moored for the protection of ports and estuaries, and the obstruction of sounds and channels, I observe that it is the business of the attacking fleet to remove these obstructions. To prevent this removal, it is generally admitted to be necessary that the line of torpedoes should be enfiladed by coast batteries. Here again the armor-plated ship has the same advantage as without the use of torpedoes.

It is true that, with very large and very efficient torpedoes, in a place well calculated for their use, and supported by very heavy and well-protected batteries, a channel can be made absolutely impervious to a fleet. But these conditions must be very heavily paid for, and no nation has such resources as to be able to expend them at every point; nor even, if wealth did not fail, would there be time to place and replace them everywhere when needed. A great point is gained in warfare, when you reduce your enemy to the alternative of using overpowering force, or of abandoning his object.

Conceding, then, that there may be an irresistible torpedo attack, but observing that this is the exceptional case which we cannot provide against, and not the general case which we may attempt to meet, it remains to be considered what must be the type and what the structure of the vessel best calculated to evade torpedo attack, and to receive, without vital injury, the attack of torpedoes of moderate size.

The avoidance of the torpedoes themselves is mainly a tactical question. Nevertheless it largely affects naval design, especially in the type of construction. Other things being alike, a small, handy vessel, with high speed and shallow draught, will avoid torpedoes better than a large ship, or than one of inferior speed or inferior power of evolution. That is evident, even when both ships have to run the gauntlet of a line of torpedoes. But the small ship of light draught has the command of many more channels, and many more parts of broad channels, than the larger craft, and will thus put the landward power to a far larger expenditure of these instruments for the protection of its coasts.

The destruction of the smaller vessel by a torpedo will also be a less expenditure of life and material than that of the larger ship. It is true that if she runs foul of one, the smaller vessel is the more likely of the two to be sunk, and that is a set-off against her facility of avoiding them; but there still remains an advantage in favor of distribution in small ships rather than of concentration in a few large ships. There is, of course, a limit to the distribution, as there is also to the possible concentration.

The principle of subdivision is one of the most effective means of meeting submarine attack; subdivision from large ships to small ships, within certain limits, and for certain purposes; and subdivision of large ships into small compartments, where size cannot be advantageously reduced. Cellular subdivision should be carried out where possible.

It is worth while to point out that the partition of a ship by bulkheads does not necessarily mean cellular subdivision. A cell is a chamber which can be completely closed, and must therefore have a tight roof, as well as floor and walls. This is of especial importance in torpedo warfare, for it is very desirable to have the power of expelling the water after it has gained admission. In a closed cell, this is easily effected by forcing in air from the top, provided that the wound be low down in the cell. I do not claim the credit of this idea. It was suggested by a paper read before this Institution by Admiral Sir E. Belcher, in 1865.*

There are great difficulties in applying this principle of subdivision to the engine and boiler rooms—perhaps insuperable difficulties. I must content myself with pointing out the general advantage in this respect of the system of subdivision, and the necessity of placing as far out of reach as possible those portions of the ship to which it cannot be applied.

I find, however, that I am not singular in the belief that the whole system of the marine engine in ships of war is in need of a thorough revolution. I have no pretension to guide this revolution—I have neither the inventive genius nor the needful preliminary knowledge for it. Others, better qualified than myself to speak on these matters, have called attention to the unwieldy size and structural weakness of the cylinders—to our boiler rooms of enormous size, yet still cramped for want of space; to our hot and unhealthy stoke-holes; to our barbarous method of stoking—barbarous in respect to cruelty, as well as of clumsiness. Is it too much to hope that the unwieldiness, as well as the other defects of the system may, at no distant period, meet with a remedy?

Cellular subdivision is the most obvious and the most important principle in saving a ship from the consequences of local injury. Armor plating applied to the bottom of a ship is doubtless a protection against submarine gunnery (a danger we have not as yet to face), but it is not an efficient defence against torpedoes. Armor plates are mere slabs, imperfectly connected both with one another and with the ship's structure, to the strength of which they contribute but very little, if even (all things considered) they do so at all. Apart from the probability of their being broken up by a quick-acting explosive, like fulminate or nitro-glycerine, the plates, or part of them, might be driven home upon the ship itself, in such a way that their edges might sheer the skin plating and frames. It would, moreover, be impossible to give them any great thickness, on account of their weight; for every cubic ft. of iron takes 7½ cubic ft. of displacement to float it.

Whenever we have to encounter the effect of violent explosions, our first object is to make as much as possible of the impact expend itself in harmless directions; our second, to endeavor to gain as much as possible the time needed to change destructive impact into mere motion. This latter is a task which a buffer performs in cushioning a blow. It gives time for the work concentrated in the impact to distribute itself through a large mass, and thus to lose the intensity which is necessary to a disruptive or disintegrating effect. By what particular device we bring this about is rather a matter of structural convenience than of defensive power. The most direct method of doing it is, doubtless, to make the explosion take place at as great a distance from the vital part of the ship—from its inner skin—as possible. Experiment and theory both lead to the conclusion that its action varies inversely as the square of the distance, and therefore the interposition of an increasing distance very soon converts its destructive effect into a mere propulsion of the ship. If it were possible to keep off the torpedo from actual contact with the ship, by any device, like the spines of a hedgehog, or a wire

* See his paper on "The Construction of Armor-clad Ships of War."—*Transactions, I.N.A.*, vol. vi., p. 75.

shield outrigged, small torpedoes would hurt her but little. For various reasons these particular devices are out of the question, and I only mention them as showing a theoretical principle which we should keep in view.

For particular service, when it is the deliberate intention to make a ship force a line of torpedoes it may be worth while to make the sacrifice of speed, and to outrig either common rope netting or wire netting, at a very considerable distance from the ship's bottom. As this netting may be outrigged to a distance of 6 or 8 ft. from the ship's skin I do not doubt that this is the best method of meeting a line of torpedoes where such a line is known to exist. But the terrible impediment which it offers to speed and handiness makes it unpractical, when the object is, on the one hand, to cruise at the risk of meeting torpedoes; or, on the other hand, to be serviceable for manœuvring after getting through them.

These considerations have suggested to me a device which (although not wholly satisfactory to my own mind) appears to me far superior to that of putting armor-plate on the bottom of a ship. It is as follows:—Let your ship have three skins, each divided into cellular spaces of moderate size,* the middle skin representing what is now the outer skin of an ordinary double-plated ship, like the Hercules or the Audacious—the cells perhaps somewhat smaller, and each with a man-hole fitted air-tight in the inner skin, and also with a pipe having a stop-cock and union collar opening into the upper corner of it. The space between the outer and inner skins is also to be divided into cells, the frames and longitudinals composing which should break joint with those between the middle and inner skins. Water is to be freely admitted between the middle and outer skins. The middle skin is to be deliberately weakened near the bottom of each inner cell.

I expect the plan to work as follows:—A torpedo explodes against the outer skin at T, the compartment, M N, being full of water, and, with the outer surface, E F, under violent pressure, must relieve itself through the middle skin. This is weakest at H G, and will therefore give way there. The torpedo will therefore have the work to do of not only driving in the outer skin, E F, and bursting the inner skin, H G, but also of getting the water out of M N into A G, against the cushion of air which the latter contains. I should think this would exhaust the work sufficiently to save the inner skin from vital injury, unless the torpedo was very powerful indeed. Then, if many cells were wounded, the cocks, K, would come into play; air would be forced into them, and would expel the water down to the level, H.

The frames and longitudinals between the middle and outer skins should be rounded, or dished, so as not to transmit a blow to the middle skin. The edges at which they meet should be joined with a covering piece of sheet-iron of half their own thickness, which would break up easily, and thus prevent the cell from behaving like a buckle-plate. The man-hole N′ would serve to take ashore for docking. I owe this very important practical suggestion to Mr. W. C. Unwin.

Without having too much faith in my own project, I prefer it very decidedly to armor-plating the bottom. I certainly add to the size of the ship, and I therefore require more propelling power. I also add to the weight, to the extent of the quantity required for all that is outside the middle skin. But this is not comparable to the weight of armor-plating, the water between the middle and outer skins have no weight in water, and therefore requiring no displacement beyond that of its own bulk to support it. Of course, the device is not applicable to small craft.

I wish to repeat that I have not written my paper to bring forward this project, but that the project occurred to me in the task which I had set myself, of considering what would be the probable effect of torpedoes on the construction of war-ships.

As regards quantities of scantlings, I do not consider myself in a condition to decide upon these points until I have before me the results of more experiments than have yet been tried, or at least published. There is no difficulty in calculating, with more or less exactness, the mechanical work due to the explosion of a certain quantity of gunpowder under certain circumstances. But when we want to know, not the total work, but the destructive impact under the influence of circumstances which have not yet been experimentally studied, we are quite at fault. For instance, I do not at all see my way to answering the question whether it would be preferable to expend the cost of

* It is an axiom of iron ship-building that no subdivision or cell should be so small as that a man cannot be sent into it and reach every part of it.

protection chiefly in the thickness of the outer skin, or rather in its distance from the middle skin; still less do I know the point at which there is equation between these. Again, I have nothing to guide me as to whether it would be better that the cells of the outer skin should or should not include an air-cushion or a water-cushion.

On all these points we must await actual experiment. I am glad to hear that experiments upon torpedoes have been undertaken, and I shall consider that a great part of my object in writing this paper has been accomplished, if it has the effect of furnishing hints for the useful direction of such experiments.

To return to the main subject of the paper. The introduction of the torpedo system greatly increases the inevitable risks of ships of war—that is to say, those risks which must be run with full knowledge of the hazard encountered, and even with the distinct notion that some not inconsiderable loss of ships and of human life is certain to occur. It is, therefore, above all things important to reduce to a minimum the crews of ships of war. To crowd together more men upon one ship than are needed for working and fighting is a deliberate waste of our most valuable resource.

One thing more. A large iron-clad of the present day is a vile place to live in. Small iron-clads, or even large iron-clads, divided into cells, will be very much worse, insomuch that every man will be a nuisance to his neighbor. With every squadron, therefore, we must send other ships, not fitted for fighting—an admiral's yacht, a hospital ship, and a floating smithy at the least. It will be much cheaper to provide accommodation separately for these purposes, than to build fighting-ships to receive non-combatants.

I believe this paper contains the first suggestion which has yet been made public for providing structural means of enabling a ship to resist torpedo attack. I regard it as a first step only. I think it just possible that, as a first step, it will be welcomed by my audience, partly for its own sake, but far rather as the harbinger of more.

In conclusion, I wish to point out that the introduction of torpedo warfare has not had for its strategic effect the paralysis of naval attack. On the contrary, it has only gone part way to neutralize the enormous preponderance which at one time the introduction of steam-power and armor-plating appeared to give to an assailant. I do not propose to discuss details which belong to the military rather than to the constructive branch of our profession; but I have much misunderstood our contemporary history if I am wrong in my belief, that, torpedoes and railways notwithstanding, the seaward enemy is far more dangerous now to the landward power, than when sails and oars were the only means of propulsion. The command of the coast still follows the mastery of the sea.

NOTE.—It may be worth while to call attention to a plan for fishing up or cutting torpedo wires, which I published in the "Engineer" for 18th November, 1870, p. 343.

ON A NEW FORM FOR IRON-CLADS.

BY CAPTAIN JOHN WHEATLEY, R.N.

From "The Journal of the Society of Arts."

In Captain Colomb's paper "On the Attack and Defence of Fleets," read at the Royal United Service Institution last April, after showing the great loss of power of the gun as a weapon, he states:—"This seems to me a very startling conclusion to arrive at, and one which lies at the root of all construction and armament. It is not as though it were certain that gun must meet gun, and therefore the recession was common to both sides of the equation, but it is that some other weapon or weapons are making tremendous strides, and are beating the gun in competition. It may mean also that the manner of constructing the carriage—that is, the ship—is at the bottom of the recession. In any case I can conceive no more important subject for inquiry than whether my figures and deductions are correct. If they are, I can only express my belief that we are close upon a very extraordinary construction of our navy."

Thus, in the opinion of a most competent judge, of an officer who has made an especial study of his subject, none of our present ships are efficient, not one fit to cope with

the new conditions of naval warfare. The weapons alluded to as beating the gun are, first, the ship used as a ram; second, the torpedo; this latter, however, making the ram a very hazardous mode of attack.

Taking the torpedo as by far the most important weapon, but without excluding the others, it will be my endeavor to bring before you a form of vessel more adapted to the altered condition of naval warfare than any now extant. Formerly, broadside on was the mode of attack, because bringing the greater number of guns to bear; with iron-clads, presenting the broadside is their weakest position, as presenting the greatest extent of penetrable armor, and laying them more open to ram and torpedo attacks. The form of vessel of which the diagrams are before you, is taken from the Eastern type, prevalent from Egypt to Japan inclusive, and of which the Bombay cotton-boat is one of the best specimens; but in my vessel the projecting bow will be prolonged to a form approaching that of the cigar-ship, for reasons which I will explain later. Her extreme length is to be 300 ft.; beam 1-4th of length, 75 ft., enabling her to carry 14 35-ton guns, weighing, with 23-ton carriages, 812 tons, little more than two turrets with their guns. These 14 guns are to be mounted on Captain Moncrieff's system, having, without altering her position, a greater weight of all-round fire than any existing form, while exposing less vulnerable surface, the guns being mounted in an oval, terminating forwards in an acute spherical angle. Her best mode of attack being stem on, she will bring eight guns firing ahead or astern parallel to the keel, the beam gun and contiguous gun firing alternately. The length of the major axis of the oval is half the extreme length, 150 ft.; any increase of the length of the oval would diminish the defence by exposing a larger surface to an attack on the broadside, while any diminution would cramp the space for working the guns. The ketch rig gives a clear deck for the same purpose, and the lateen form of head sails tends more than the present form to lift the bow, ease the pitching motion, and so to increase the speed. On looking over vol. v. of your "Transactions," I found that one of your vice-presidents, Admiral Sir Edward Belcher, had proposed, in 1829, to sail an 18-gun brig stern foremost and ketch-rigged; so I trust that this proposal to carry out similar principles on a larger scale will obtain his approbation.

The proposed beam is necessary to admit of a powerful battery firing ahead or astern in attacking or retreating, and only seems excessive through the size our ships have attained; proportionately it is not greater than that of our former wooden ships.

I now come to the long projecting bow. In the discussion on Captain Colomb's second paper "On the Attack and Defence of Fleets," at the Royal United Service Institution, on the 15th of January last, the question was asked, "How would you attack an enemy's fleet, supposing each ship of the enemy towing a Harvey torpedo on each side?" It appears to me that the result, whether with fleets or single ships, would be in favor of the party giving the first hits with the torpedo, and that this would be best obtained by an outrigger of the length of a late first-rate's jib-boom, about 70 ft., with a housing of 12 or 15 ft. from the projecting stem of my vessel. Again, this form of stem would tow two other torpedoes, one on each side, with not more than three or four fathoms of line, all three at the requisite depth under water to secure an effective explosion, while the form of stem under water exposes less surface to an attacking torpedo than any ship of the present form. Should an enemy's ship approach with an intention to ram, the towing torpedoes may be allowed to run out the line till the torpedo has crossed her course, and then, the break being applied, she will be at once destroyed.

Vessels of this form will have greater buoyancy than those of the present form, and therefore would carry thicker armor, and if requiring ballast to steady her in rolling, it might be applied in thicker bottom plates; but these are subjects that specially belong to the naval architect.

Another advantage of this form is, that it gives greater rapidity in turning, thus enabling her more readily to avoid sudden attacks by ram or torpedo, and punishing the attempt with her stem or her guns.

As to guns, without disputing the superiority of the rifled gun when, as on shore, the platform and the object are both fixed, at sea I should prefer the smooth-bore, giving the advantage of ricochet firing, where platform and object are both in motion, and the range ever changing, and also for the power of using grape-shot.

In the encounter between the Royal Sovereign and the Camel, with Harvey's torpe-

does, it may be assumed that had the Royal Sovereign's 25-ton guns been smooth-bores, and using grape-shot in proportion to the round shot they would throw, the Camel would have been defeated on her first attack. As the case now stands, this torpedo success condemns the whole turret system. A 35-ton gun would probably admit of an 18-in. bore, throwing an 800 lbs. shot; and a cluster of grape of, say 12 7-in. 50 lbs. shot, would, with disk and rod, be of about the same weight, and speedily settle any unarmored or light-armored ram, gun, or torpedo vessel venturing within range, and thus, in some measure, restoring some of the lost power of the gun.

According to my experiehce, every vessel moving through the water, except before the wind, raises a sea against her in proportion to her bulk, speed, and weight. This is visible even in the gentle movements of an aquatic bird in water, elsewhere as smooth as a plate of glass, and in buoys and piers of bridges in a tide-way. In an account of the visit of Comodore Perry, of the United States Navy, to Japan, I find it stated that "the heavy sea at the landing-place caused a long delay in embarking. . . . At last when all were embarked, a further advantage of the Japanese boats, whose superior speed was already known, was manifest in the fact that all who were in the Japanese boat arrived at the ship quite dry, while those in the American boats were thoroughly drenched." From this fact, I put it to the consideration of naval architects whether, seeing that ramming is hardly possible in the face of the torpedo, a total change in the form of the bow of the breastwork monitors to that on the principle here proposed might enable them to face the sea, which more than one example shows that they are now not able to do.

To conclude. Considering that living on an island not producing sufficient food for the population, our commerce is our life, that we could not exist in our present numbers without it, a hostile fleet at sea unopposed would be even more fatal than a landing on our shores; that thus the absolute necessity of attack is forced upon us; and that, as far as I am aware, no answer has been given to the question, How is that fleet to be attacked with a reasonable chance of success? it has been my endeavor, according to my ability, to show how this may be effected.

SECTIONAL STEAM-BOILERS.

From "The Engineer."

Many years have elapsed since Dr. Alban laid down the axiom, that as it was impossible to prevent boilers from bursting, they should be so designed that their explosion would not be dangerous. It is only within the last eight or ten years, however, that any vigorous attempt has been made—we shall not say to invent—but to popularize the use of sectional steam generators, that is to say, of boilers composed of a number of distinct parts or sections, any one of which may burst without entailing fatal consequences on those near the boiler at the time. It is by no means an easy task to design a good sectional boiler. Those which look very well on paper do not always work well in practice; and large numbers of boilers which promised to be successful have proved utter failures. We shall not attempt just now to consider why. We can assert, instead, that many of the difficulties which have hitherto been encountered in designing, constructing, and working sectional boilers are already overcome, and that there is a fair prospect that, for land stationary purposes at least, sectional steam generators will within a few years come into very extended use. Of the safety of such boilers there can be no doubt. There is no recorded instance, so far as our knowledge extends, of a disastrous result following on the explosion of a sectional boiler. As regards their efficiency, their economy, or their durability, we regret that we are unable to speak so favorably. Their imperfections and shortcomings in these respects will, however, we think, be remedied in time; and so, all things considered, we regard the future of the sectional boiler hopefully.

Bacon's well-known adage, that "experience is the foundation of all knowledge," has been worked well-nigh to death by hard service, yet we use it here because it embodies a truth too much neglected by engineers. Of all known sciences, none depend so much on the teaching of experience as the science of mechanical construc-

tion. The mechanical engineer can never predicate anything with certainty when he has to deal with a new thing. We do not mean to assert that it is impossible to form a tolerably accurate estimate concerning a new machine or structure, but we do assert that it is impossible to be certain that the estimate will be accurate; and this statement is specially true of steam generators. No one can tell, when he is designing a boiler of a totally novel type, whether it will work well or not, and in no branch of mechanical engineering is there a greater dearth of the records of the results of experiments than in that branch which concerns itself with the design and construction of steam boilers. Scores of novel designs have been carried out and tested by experiment, it is true; but the results have either been imperfectly recorded, or kept secret by men who did not care to announce to the world that they had been unsuccessful. In boiler engineering, no one can tell what he can do till he tries. It is matter for regret that the scientific world does not know more than it does of the results obtained by men who have tried. Even such particulars as we do possess are for the most part imperfect. Those who supply them are almost invariably inaccurate; usually because they do not know how to secure accuracy; sometimes because they deceive themselves; occasionally because they wish to deceive the public. There are three great points to be attended to in designing any steam boiler:—In the first place, it should be safe; in the second, it should be economical of fuel; in the third, it should be efficient—in other words, it should steam well. That it should be cheap and easily repaired are scarcely secondary conditions of success. Now, as regards Cornish, Lancashire, egg-ended, and multitubular boilers, nearly everything is known that need be known. There is information wanted on a few points concerning them, but it is not very essential information. As regards the sectional type of boilers—which will, probably, to some extent, supersede the ordinary fixed land boiler—however, there is little or no information in existence. Nothing, or next to nothing, is known about the durability, economy, or efficiency of almost any one of the six or eight varieties of sectional boiler now in the English and American markets. Thus, having put the actual position of affairs as regards boiler engineering—and sectional boiler engineering in particular—before our readers in what we have just written, we shall now proceed to supply such information as lies in our power concerning five different species of boiler, all of which are in use in the United States, while one, at least, is being extensively adopted in England. For this information we are indebted to the report of a committee appointed to test steam boilers at the American Institute Exhibition in 1871, a copy of which we have recently received.

The generators tested are known as the Root, the Allen, the Phleger, the Lowe, and the Blanchard boilers. The first three are sectional boilers. The Lowe boiler is a horizontal tubular generator, while the Blanchard boiler is of the vertical fire-tube type. In testing the boilers, the utmost care was used to secure accurate results; nevertheless, the experiments are not quite unexceptionable. Taken as a whole, however, they constitute the most reliable investigation into the relative merits of different steam boilers, particulars of which have yet been made public. The ordinary system of testing a boiler consists in filling it up to a certain point, marking the gauge glass at that point when steam is up to the working pressure, letting the fire burn down to a few embers, supplying it with weighed coal, and then working the boiler for a given number of hours, and noting the weight of water pumped in and that of the coal burned. In the end the fire is allowed to burn down to a few embers, and the water is brought to the same level as at starting. The weight of water pumped in, divided by the weight in pounds of the coal burned, gives the evaporative economic efficiency of the boiler. The weight of water evaporated per square foot of heating surface per hour gives its absolute evaporative efficiency, which, we need hardly say, is a very different thing. Now, this system of test is very accurate, and good in all respects but one. It takes no cognizance of the fact that a great deal of water may be primed out of the boiler, and not evaporated at all. This is a most important defect, inasmuch as the worse may be made to appear the better of two boilers. For example, suppose one boiler evaporates 7 lbs. of water per pound of coal, and another evaporates but 6.5 lbs., and discharges, as priming, 1.5 lb.; then, apparently, the latter boiler would be the better of the two

in the ratio of 8 lbs. to 7 lbs., while it was really worse, not only because it did not take up so much heat as its rival from the fuel, but because it possessed the grave defect of priming heavily as well. Now, priming is a very subtle phenomenon. It is very difficult to say whether it is or is not taking place when the quantity of water passing off with the steam is small. In order not only to detect the presence of water in the steam, but to measure the precise quantity present, the committee whose proceedings we are now considering adopted the following plan:—A large wooden tank was prepared, in which was built a surface condenser, having about 1,100 sq. ft. of cooling surface. The condenser was made by connecting up the requisite number of tubes, obtained from the Root Steam Engine Company, the peculiar method of connection adopted in the Root boiler affording excellent facilities for so doing. Water from the hydrants was led through Worthington meters into the lower part of the tank, and, rising among the tubes of the condenser, overflowed at the top. The steam from the boiler on trial entered the tubes at the top of the condenser, and the water of condensation flowed out at the lowest point. The currents of steam and of condensing water thus moved in opposite directions, and the steam was condensed completely with the least possible quantity of condensing water. Thermometers were carefully made for the occasion by G. Tagliabue, and were placed as follows: One having a scale ranging from 30 deg. to 101 deg. Fahr. was placed at the inlet of the injection water, and its reading indicated the temperature of both feed and injection; one ranging from 100 deg. to 175 deg. Fahr., was placed at the mouth of the overflow pipe, and showed the temperature of the condensing water when discharged from the tank; one thermometer, with a range of from 45 deg. to 175 deg. Fahr. was so placed as to indicate the temperature of water of condensation when leaving the condenser. Another thermometer was placed in the steam space of the boiler. The pressure of the steam was indicated by two recording gauges, and the feed-water used was accurately weighed, 300 lbs. at a time. It is obvious that all the heat taken up by the water in the boilers, less that due to the radiation or conduction from the heated metal, must find its way under this arrangement to the water in the surface condenser. Taking the load on the safety valve at 76 lbs., we have a total of 1,180 units of heat in round numbers for every pound of *steam* sent into the surface condenser, that is to say, each pound of steam would raise 1,180 lbs. of condensing water 1 deg., or 118 lbs. of water 10 deg., but each pound of *water* passing away to the surface condenser unevaporated would bring to the water in the condenser but 320 units of heat.

Now it is very easy to determine, with these data before us, exactly how much a given weight of water going into a boiler, and converted into steam, ought to raise in temperature a given weight of water going into a surface condenser; and if we find that the condensing water is not as hot as it should be, then we know that all the water fed into the boiler is not being converted into steam; and, as the next step, a very simple calculation will determine how much is evaporated and how much leaves the boiler as priming. When a test is carried out in this way it is, with proper care, quite possible to determine the amount of priming within a minute fraction of 1 per cent. of the whole weight of water fed into the boiler. The surface of heated water exposed by the condenser tank was very considerable, and precautions were taken to register the exact quantity of water passing off by evaporation from this open surface. This was effected by placing a cup of water in the tank, at the top of the condenser, at such height that the level of the water inside and outside the cup were the same, noting the difference of temperature of the water in the cup and at the overflow, and the loss by evaporation from the cup. The amount of evaporation from the surface of the water in the cup and in the condenser, which latter was exposed to the air, was considered as approximately proportional to the tension of vapor due to their temperatures, and was so taken in the estimate. In testing the boilers, steam was first raised to the required full working pressure with wood only. As soon as the safety valve blew off freely the use of coal commenced, and the steam was turned into the condenser. Each trial lasted twelve hours, and when it was over, the fire on the grate was at once drawn and weighed, the weight being put to the credit of the boiler.

We now come to the results obtained, which admit of being very briefly stated. The Root boiler, with 27 sq. ft. of grate, and 876½ sq. ft. of heating surface, evapo-

rated 7.34 lbs. of water per lb. of coal; temperature of feed, 46 deg. The Allen boiler, with 32¼ sq. ft. of grate, and 920 sq. ft. of heating surface, evaporated 7.38 lbs. of water per lb. of coal; temperature of feed, 75½ deg. There was no trace of priming, but, on the contrary, a slight superheating with both these boilers. The Phleger boiler, with 23 sq. ft. of grate, and 600 sq. ft. of heating surface, evaporated 7.07 lbs. of water; feed, 45.65 deg. The Lowe boiler, with 37¾ sq. ft. of grate, and 913 sq. ft. of heating surface, evaporated 7.20 lbs. of water; feed, 45 deg.; and the Blanchard boiler, with 8½ sq. ft. of grate, and 440 sq. ft. of heating surface, evaporated 8 lbs. of water per lb. of coal; feed, 44.4 deg. The last three boilers all primed slightly, the amount of water so leaving the boiler being 3.26 per cent. with the Phleger, 6.9 per cent. with the Lowe, and 3 per cent. with the Blanchard generators. The coal was of excellent quality, containing 91 per cent. of pure carbon and 5.51 of combustible gas.

The first fact rendered apparent by the foregoing figures is that not one of the boilers tested can lay any claim to be considered exceptionally economical. They all gave a very fair result, but none of them gave a better result than can be had from a good Lancashire boiler. Quite as good, if not better, results have been regularly obtained from small multitubular boilers, while, as regards vertical boilers, two of them could be named which, though of small size, are more economical. We may cite one presenting some features of novelty which we tested a few weeks since, and found to evaporate into perfectly dry steam as much as 9 lbs. of water from a temperature of 41 deg. per lb. of coal; and it was a very little boiler, too, being only 4-horse power.

We have no fault, however, to find with the boilers under consideration as regards evaporation. That is quite up to the average of good practice in boiler engineering in this country. The real objection lies in the fact that they were one and all slow steamers. The little vertical 4-horse boiler to which we have just referred evaporated 336 lbs. per hour of water with a total surface of about 75 sq. ft., or 4.48 lbs. per sq. ft.; and this is in nowise a remarkable rate of steaming. Indeed, we once watched the performance of two egg-ended boilers, possessing together 450 sq. ft. of heating surface. These boilers regularly evaporated 120 cubic ft. of water per hour, or 16.5 lbs. per sq. ft. of surface. These were furnace boilers, however, intensely heated. An evaporation of 5 lbs. or 6 lbs. of water per ft. of surface per hour may be taken as that commonly realized in ordinary practice. The American boilers, however, did nothing approaching to this. The Root boiler evaporated during the trial only 2.65 lbs., the Allen but 3.59 lbs., the Phleger but 2.83 lbs., the Lowe but 3.10 lbs., and the Blanchard only 1.92 lbs. of water per sq. ft. of heating surface. It is fair to the Root boiler to add that its fires were allowed to get far too low during a portion of the trial. From these figures it would appear that, for each effective horse-power, taking 40 lbs. of steam per hour as equivalent to a horse-power, the Root boiler would require about 15 sq. ft. of surface, the Allen boiler about 11 sq. ft., the Phleger boiler about 14 sq. ft., the Lowe boiler about 12.75 sq. ft., and the Blanchard about 21 sq. ft. Heating surface costs money, and, other things being equal, that boiler is cheapest which requires the least amount of heating surface to do a given amount of work. It is quite possible, however, that all the boilers while under test were worked much below their regular rates of steaming. If this were so, however, it remains to be proved that the test accurately represents the economical efficiency of the boilers, which would probably be reduced if the fires were forced. On this point, however, we have no evidence whatever, and so we must leave our readers to draw their own conclusions from such data as we have been able to place before them.

The whole number of acres of land which have as yet produced petroleum, is stated by the Titusville "Courier" to be about 6,500—equal to ten square miles. This plot of land, constituting about one two-hundreth part of what is known as "The Oil Region," produced during the year 1871, 5,790,000 barrels of oil, which at $4.50 per barrel—the average price for the year—reaches the snug sum of $26,055,000. The same region has produced since 1859, 33,301,000 barrels of oil, which probably yielded not far from $160,000,000. And so far is this wonderful region from being exhausted, that the value of the land is greater today than at any time since the discovery of oil, except during the times of the great excitement in 1865.

MASONRY AND BRICKWORK.

From "Engineering."

However gigantic may be the strides with which engineering science has advanced during the last few years, it cannot be denied that, so far as regards the special art of building in masonry or brickwork, the present race of architects and engineers are feeble in conception, timid in execution, and but dwarfs of utter insignificance as compared with the giants of former days.

It would be amusing, or more truly perhaps the reverse, to note in what manner an average architect or engineer of the present age would deal with some of the problems presented to the old masters, for instance, such a one as that successfully solved by the Saracenic builder of the justly celebrated tomb of Mahomet at Bejapore, India, which was as follows: Given a building 135 ft. sq. on plan, and 110 ft. high, required to cover the same with a circular dome 124 ft. in diameter, and weighing some 12,000 or 14,000 tons. It would be curious to observe how many hundreds of tons of iron our men would consider it imperative to throw into the work. The Saracen, knowing the capabilities of his material, asked for no ironwork, but fearlessly trusted to his masonry, and skilfully corbelled out the square walls at the top to meet and support the circular dome, and to such a bold extent, that at the angles of the building the projection of the corbelling measured no less than 46 ft.

How infantile appear the greatest exertions of our modern building in comparison with such mammoth works as these. The traditions of the art have been lost, and science has provided no substitute. Our professors, if they do not avoid the subject altogether, treat it in a perfunctory, *ignotum per ignotius*, manner, which only serves to make the "darkness more visible," or the "little glooming light"—which may already exist in the student's mind—"more like a shade." We may be taught, for instance, that the line of pressure in an arch must be included in the middle third of its depth, or the arch will tumble down, and we may be treated to many other equally shallow *dicta* based upon hypotheses evolved from purely theoretical considerations, which the bare existence of hundreds of buildings for hundreds of years conclusively demonstrates to be utterly false and untenable.

In recent times, no doubt, the introduction of ironwork has had much to do with the extinction or suppression of nearly all that is true and expressive in the art of building. It is so very easy to multiply the span and divide by the depth, and to perform the other elementary operations incidental to the determination of the strength of an iron girder; and then, besides, the figures and diagrams look so clever as to induce in the too often shallow performer a glow of self-complacency, leading him to fervently believe that an engineering feat has really been achieved. But if such work constituted engineering, the schoolmaster in the "Deserted Village" would be an admirable exponent of the science.

> The village all confessed how much he knew,
> 'Twas certain he could write, and cipher too.

Another advantage offered by ironwork as compared with masonry, and one to indolent or incompetent men peculiarly seductive—is that of shirking responsibility. With iron girders the designer may devote the few minutes necessary to the conventional calculations, specify iron of a given strength, and so rid himself lightly of any further sense of being responsible. But if, on the other hand, his first consideration is his client's interest, and not his own ease, he will often be led to discard ironwork in favor of masonry, and he will find no royal road to learning in that direction, but must honestly and laboriously qualify himself by theoretical and practical investigation, and by comprehensive analyses of works already executed to form a correct estimate of the capabilities of the masonry or brickwork with which he may be dealing, and to shape his design accordingly.

Notwithstanding the eclipse which constructive masonry has suffered by the advent of ironwork, a very important part is still reserved for brickwork to play. The value of the brick dwellings and other structures annually erected in this country far exceeds that of any other similar class of work, railway or otherwise. How trustworthy a material brickwork is, may be considered self-evident, when it is remembered that amongst the hundreds of thousands of brick houses in progress or in existence, the fall of one rarely or ever occurs

unless it be either very old and decayed, or young and green, and this, notwithstanding the disadvantage these structures labor under in being proportioned as regards strength by mere rule of thumb, or by no rule at all. Our architects have, in one small respect, improved upon the practice of their immediate predecessors by reason of the omission in their buildings of that potent agent of destruction—timber bond. They have learnt that modern bricks and mortar can be made to rival in durability any material that the Romans employed, and that the alleged peculiar virtues of ancient mortar are mythical, or due solely to age. Good bricks and mortar, when once in place, require no painting or further attention, and instead of deteriorating, like ironwork, brickwork positively increases in strength, to an appreciable extent, during the course of many years. In fact, so many advantages, as regards cost and durability, are offered by brickwork, that the rush upon ironwork made by the second-rate men of the engineering and architectural professions is much to be regretted, both in the interests of the art of building itself, and of its patrons' pockets.

A little knowledge is proverbially dangerous. It is therefore no matter for surprise that so-called utterly ignorant country builders are, as a body, more just to their clients than many pretentious but half-informed professionals. The absence of classified experimental data relating to the properties of brickwork may be urged by some as a valid excuse for the indifference or ignorance evidenced by the latter body, but this argument cannot be sustained. Many experiments are not needed, for, if the eyes be but kept open, the thousands of houses which are continually being run up by speculative builders, with their numerous small but suggestive defects, readily traceable to defective design or materials, or to both conjoined, furnish the thoughtful observer with data for generalization of far greater value than could be obtained from the most elaborate series of experiments.

Looking broadly at the respective practices of engineers and builders when dealing with brickwork, it may be said that engineers, in their calculations, treat their bricks as so many Lilliputian blocks of stone piled upon each other, and kept in place solely by the action of gravity, whilst builders, on the other hand, treat them as so many blocks of more or less irregular shape firmly glued together into one solid mass. Engineers act upon the latter theory by compulsion, when dealing with concrete; but the extensive use of the latter material in recent times has not made them a whit less exacting in the precise arrangement of the spiral courses of a skew brick bridge, or in many other farcical niceties of a similar nature.

The daily personal experience of practical builders has formed the basis of their theory, and they know the conditions to be complied with in order to insure success. Brickwork laid in irregular courses, arches with theoretically inadequate abutments, and concrete structures of any class, will tumble down if not sustained by extraneous aid when young and green, and yet a few days or a few months later they may be possessed of a surplusage of power to undertake any duty which may be imposed upon them. Builders know this truth, and act upon it; hence it is that in so many cases where an engineer would introduce ironwork, the builder simply substitutes sound cement for his ordinary mortar.

Few things can be more instructive to an earnest student of constructive art than to note the various shifts and contrivances practised by a speculative builder in carrying out such a work, for instance, as a row of shops, when conditions of a pecuniary nature necessitate everything being cut down to the lowest margin of strength that his experience can justify. The whole front of the buildings, for some hundreds of feet perhaps in length, will be carried upon a series of light timber brestsummers, resting at each end for a length of 4 in. upon the party walls, and propped up temporarily at some intermediate point by a thin story post, which has sprung very probably 2 in. or more at the centre, in consequence of the excessive weight thrown upon it by the green brickwork. At the corner the building will present the fearful and wonderful appearance of a house built upon a Brobdignagian kitchen table, and only prevented from plunging off the table to its own destruction by the gentle persuasion of a couple of slight raking struts temporarily fixed at the angles. So appears the row of buildings for some months, whilst the internal finishings are in progress, and then comes the time for the striking of the struts and the setting up of story posts, to be followed by the putting in of shop fronts and the general polishing up of the exterior,

when the building presents the appearance of those to which the public are accustomed, into which they enter, and in which they dance about without the slightest trepidation or suspicion of ever so small a risk.

Now, if this model row of shops were submitted for report to an average young engineer fresh from King's College, he would conclusively demonstrate to his own satisfaction that the building could never stand; that the brestsummers were loaded nearly up to, or perhaps even beyond, the breaking weight; that the bearings at the ends, instead of being mere ledges of 4 in., should be broad and substantial bed plates; and that by reason of the unequal strains induced by the weight of the entire front of the house, together with that of the floors and roof resting upon it, being thrown upon the extreme verge of the party walls, the brickwork at those points would encounter strains which it is utterly incapable successfully to resist. The building does *not* come down, but our young friend will simply disclaim any responsibility for the inexcusable conduct of the building in that respect, and, proudly conscious of the immutability of mathematical laws, and of his own proficiency therein, will content himself with reasserting his theorem that the building ought to fall. This conclusion is, of course, essentially indolent and unscientific; the truly scientific course to adopt would be to endeavor, by a process of induction, to reconcile the apparent discrepancy between theory and practice.

The elements of reconciliation will be found in the fact that brickwork is possessed of many valuable attributes which are taken advantage of by the builder, but are ignored by the engineer in his calculations, although not unfrequently they generously come to his aid, and save his credit in cases where he has hopelessly blundered even in the application of his own theory. The modern class of builders have arrived at their present position by a tentative process. At one time, a so-termed brick house consisted in reality of a self-sustaining timber framework filled in with brick panels, and at a more recent period bond timbers were introduced wherever the fancy of the architect dictated. The superstition that these bond timbers performed an essential function would appear to enjoy a flickering existence even at the present time, for in one of the most recent and important additions to railway works in the metropolis, hoop-iron bond was extensively introduced in almost every conceivable position—for instance, in courses parallel to the abutments throughout the entire length of the arches, although they might be so long as to resemble a tunnel. This, happily, is rather a unique specimen of railway practice, but it serves well to illustrate the direction in which engineers commonly err in their estimate of the capabilities of brickwork.

The subject of which we have been speaking is a most important one, and we intend to have more to say upon it shortly.

ON THE PROTECTION OF VESSELS AGAINST TORPEDOES.*

From the "Journal of the Society of Arts."

The damage caused by torpedoes and guns to the immersed portion of the hull of a man-of-war is already well known, and with the progress of artillery science this damage will always tend to increase. With the present system of construction, the whole surface of the ship's body below the waterline, or rather below the armor-plates, is defenceless, and for this reason I consider it the duty of every technical man to endeavor to devise some remedy against torpedoes and submarine guns.

With this view, I made some trials on a small scale some years ago, and, subsequently to these, trials on a large scale took place at Shoeburyness, with cotton and cork, though not with the ingredients hereinafter described. My paper to-day is intended as a hint towards further experiments. For this purpose I have got out Fig. 1, showing how old ships may be protected, and if a good result be obtained, it will be known how to protect good ones.

I have taken wood as the building material, because I consider that wood treated with tar steam in an apparatus patented by Mr. T. Rosthorn, whereby the saturation is

* By HERR J. N. MOERATH, Chief Engineer, Austrian Navy, and Permanent Member of the Imperial and Royal Shipbuilding Commission at Trieste.

not merely superficial, but penetrates into the very heart of the wood, will be much used in the future.

It is known that men-of-war built of iron, laying sometimes several months continuously in a harbor without being moved, become weakened on account of the galvanic action set up in the large metallic surface bathed in sea-water. This weakness is very dangerous to iron ships as regards torpedoes and other shocks under water.

The protection referred to consists of a second armor, composed of various sections, *a*, *a*, *a*, fixed with bolts to the ship's hull, and constructed of tinned sheet iron, riveted together with angle irons, and filled in with cork shavings and hydraulic chalk, mixed with silicate of soda* (in German, *wasserglas*). This filling gets dry in a short time. The greater carrying capability of such a double-armored ship admits of strengthening the hull by continuing the iron armor, *b*, *b*, *b*, by comparatively strong sheet-iron plates, *c*, *c*, *c*, riveted together, as shown in the diagram. The filling also, on account of its ductility, decreases the destructive effects of projectiles or of torpedoes, as the velocity of the projectile diminishes in passing through this mass, so that it cannot act with its full power on the iron armor plates, and the ship is, of course, saved from great damage, and consequently from immediate sinking, while a possibility is afforded of repairing the damage in the nearest harbor. The holes caused by repeated shots striking this armor can easily be repaired, both in the ship's hull and in the iron armor plates, and the damaged sections can be replaced by new ones.

In addition to the great advantage of a ship's being enabled to carry very heavy guns by the adoption of this mode of protection, there is another, viz., that the internal shape may be any that best accommodates the machinery and artillery, while a suitable external form for a high rate of speed can be given by the surface of the protecting armor. In order not to diminish the ship's speed, the engine power must, of course, be in proportion to the increase in the area of the transverse section.

FROM PIG TO PUDDLED BAR.

From "The Engineer."

The mechanician and the chemist have for many years found in the manufacture of iron an attractive subject for investigation; and their investigations have been followed by an almost unparalleled number of inventions for simplifying, cheapening, or improving the various processes by which ore or "mine" is converted into pig, and pig into puddled bar or wrought iron. A very large proportion of these inventions has proved unsuccessful in practice, and we think the reason is not difficult to find. Simple as may appear the processes of smelting the ore or puddling the resulting pig to those possessing but a superficial knowledge of the subject, it is certain that these operations are in no small degree recondite and complex, especially in the chemical reactions which take place in the blast and the puddling furnace. With the former we have for the moment nothing to do, and we shall therefore confine our attention solely to the process of converting pig iron into puddled bar. With the general features of this process every one of our readers is no doubt familiar. The iron must first be melted, and while melted it must be exposed to the action of some agent which will remove the carbon, and, if possible, the phosphorus and sulphur with which to a greater or smaller extent nearly all brands of cast iron are contaminated. Practically, the only available agent is oxygen. This easily lays hold of the carbon in the iron at high temperatures and burns it out. The removal of sulphur and phosphorus is infinitely more difficult, because of the remarkable affinity these elements possess for iron. It is fortunate, that whereas we cannot have wrought iron at all if more than a very small percentage of carbon is present, we can have fairly good wrought iron, useful for many purposes, even though none of the phosphorus or sulphur orginally in the pig be eliminated. It is not too much to say, that if it were as difficult to get rid of the carbon as it is to get rid of the other two elements, we should have little or no wrought iron. The labor of inventors has hitherto been devoted to two distinct objects.

* Ransome's apparatus for making wasserglas. "Technologiste," 1857, p. 867.

The first is to simplify and improve upon the methods ordinarily practised for getting rid of carbon; and the second is to devise means by which the phosphorus and sulphur can be disposed of. Under the first head may be ranked the Bessemer process, and the various systems of mechanical puddling which have been invented and tried with varying success. The principal object sought to be attained has been to dispense with or to lessen the labor of the puddler. No process exists which will give as good a result as regards quality as the old system of puddling when carried out in perfection, but the labor and cost of the process are excessive, and might be reduced with enormous advantage to the iron trade; consequently we have a distinct class of inventors, such as Menelaus and Danks, all working to this end. As regards the elimination of phosphorus and sulphur, totally different methods of manufacture are required; to remove carbon cheaply and quickly, has become the task of the mechanical engineer; to eliminate sulphur, phosphorus, and silicon we must resort for assistance to the chemist. As the affinity of these hurtful elements for iron is too great to prevent their removal by oxygen alone, we must bring them into contact with some other element which, under a high temperature, will combine with and remove them. Chemists are acquainted with many such substances. Among the most important are the halogens:—Chlorine, fluorine, and bromine. These, if properly used under the requisite conditions, will probably do all we want done. The principal difficulty lies in securing the conditions. A class of inventors has been called into existence by this fact, whose entire exertions are devoted to devising the best means of utilizing the chemical forces which we know are available for the purification of iron. Hitherto these gentlemen have met with very doubtful success. They are known in the iron trade as "physickers," because they introduce into the furnace what puddlers call "physick"—that is to say, some chemical including in its composition chlorine, bromine, or iodine. The most recent inventions in this direction come from the United States. Not long since we gave in detail the results of experiments carried out in our presence at the works of Sir John Brown and Co., Sheffield, by Mr. Sherman, of New York; and about the same time Mr. Henderson, another American gentleman, was attracting a good deal of attention by another process having the same object in view, but carried out in a different way. The essential nature of the Sherman and Henderson processes is the same; but whereas Mr. Sherman elects to use iodine, Mr. Henderson has chosen fluorine. Mr. Sherman carries his chemical compounds in his waistcoat pocket, but Mr. Henderson brings his to the works in casks. We shall not further refer to the Sherman process. Mr. Henderson, however, has been for some time in England experimenting at various works, and as his process really appears to possess a good deal of promise we shall place our readers in possession of the results of our own somewhat limited acquaintance with its practical working. We believe that we were the first in England to give a detailed account of Mr. Henderson's views, and we must refer such of our readers as desire to master the whole subject to our impression for Feb. 17th, 1871. We shall now record the result of two experiments made by the courtesy of Mr. Jeavons of the Millwall Ironworks, at Millwall, on Tuesday last.

There is at present but one puddling furnace at the Millwall Ironworks—which have come into Mr. Jeavons' possession within a comparatively recent period—a new forge being now in course of erection. This puddling furnace delivers the products of combustion straight into a lofty stack, and is of very good construction, with the exception that the grate is rather too large in our opinion for economical working. However, this, as regards the make of iron, is an error on the right side. When we arrived, at about half-past 11 A. M., we found the furnace lit up and hot; the bottom was of cinder. We cannot better describe the experiments than in the form of a diary.

At 11.52 A. M. the puddlers began to fettle with ground hematite; when the fettling was so far complete, half a dozen shovelfuls of mill scale were thrown in. The "physick" was then introduced; it consisted of 152 lbs. of ilmenite, and 56 lbs. of fluor spar, ground to a very fine powder and intimately mixed. As soon as this powder had been evenly distributed over the hearth, four pieces of thin board were laid with a peel on the powder, and on these the pig iron was charged as quickly as possible. The board is intended to prevent the disturbance of the chemical compound. The charge consisted of 4 cwt. of very grey, Car-

ron No. 4, pig. The operation of charging ended at 12.14 P. M., when the door was closed and firing up began. At 1.14 P. M. the iron—which was not touched in any way—was all melted. Up to this time the furnace had worked very cold, which accounts for the delay in the melting, but during the rest of the process there was nothing to complain of on this score. At 1.20 a few small pieces of pig remained unmelted, but in the larger portion of the hearth a sensible reaction had set in; at 1.32 the whole was boiling quietly; at 1.42 the iron had risen a little; at 1.50 it boiled freely; at 2.14 the boiling was less rapid; at 2.47 there was no change; at 2.58 all the reaction appeared to be over, and Mr. Henderson reluctantly resorted to the aid of the puddler. As soon as the iron was stirred it rose rapidly, and came quickly to nature. But it was discovered almost the moment that the rabble was introduced that a cake of wrought iron lay on the bottom of the furnace, and it was not until 3.48, after excessive trouble, that two small balls were got out and taken to the hammer. A third ball weighing about 20 lbs. was afterwards got out with the aid of a bar and sledge. It will be seen that, from the time the iron was melted till the first balls were drawn, not less than 2 hours 28 minutes elapsed. Ordinarily the charge would have been all drawn in about 1 hour 40 minutes from the time of putting in the pig. The consumption of coal was, of course, very large, and the yield of iron very low. The balls worked well under the hammer and in the rolls; when broken an examination of the grain was sufficient to show that Mr. Henderson had not made wrought iron, but puddled steel; so far the process was a failure. This the inventor attributed to the fact that the furnace had worked too cold.

At 4.10 P. M. the operation of charging a second heat commenced. This time Mr. Henderson abandoned the use of ilmenite, which is intended to carry off phosphorus as vapor, and used 56 lbs. fluor spar intimately mixed with 56 lbs. of old firebrick ground to a fine powder. The charge consisted as before of 4 cwt. of Carron No. 4 pig. At 4.15 it was all in and the door dropped; at 5.25 it was all melted, and began to boil strongly. This condition remained unchanged, the furnace working excessively hot—the damper being full open, and the firing vigorous—until 5.55, when the iron rose and boiled over at the puddling hole, a large proportion of the cinder being thus wasted. The metal came to nature immediately, and the operation of balling commenced. As in the first experiment, so now, the operation was effected with difficulty, the iron adhering strongly to the bottom of the furnace; so strongly, indeed, that to get out the last of it a sledge and bar was needed, and the furnace was not finally cleared and the cinder tapped off till 6.46. The two balls got out worked fairly, under the hammer, but they required much management. Mr. Jeavons could not roll them off that night, but they were rolled off on Wednesday, we believe, and samples will be sent to Mr. Kirkaldy to be tested.

For the present we prefer to make little or no comment on the Henderson process. Its inventor has proved that in the ordinary puddling furnace he can make puddled steel without the aid of the rabble; but it is certain that in our presence he achieved none of the remarkable results we were promised by some of our contemporaries. It is evident, however, that Mr. Henderson would have done very much better if he had permitted a moderate use of the rabble, which would have prevented the caking of the iron and reduced the time of working. We hope to have an analysis of the iron produced, in a short time, when we shall probably return to the subject.

Leaving now the chemical processes, let us turn for a moment to the mechanical. About Mr. Danks, and about the host of rivals or imitators who have started up since he achieved success, it is unnecessary to speak. Our readers have been kept *au fait* with every phase of the rotary puddling furnace. In another page will be found a paper read on Wednesday evening before the Society of Arts which deserves more than passing attention. Mr. Jeavons, in a spirit which deserves all praise, has afforded M. Dormoy an opportunity of showing his rotary rabble in action in this country, and we can assure ironmasters that it is worth a trip even from the North to London to see a charge puddled by its aid. We published an account of this invention in a recent impression, and we confess without hesitation that we then set it down rather as a mechanical curiosity than as being an invention likely to play an important part in the iron trade of this or any other country. We found that the puddling furnace used by Mr. Henderson at Millwall was fitted up

with the requisite tackle, and we learned in the course of the afternoon that M. Dormoy proposed to puddle a charge to ascertain if the mechanism was in order. This trial was in no way intended to show the merits of the process, but simply to test the tackle. M. Dormoy, however, very courteously granted us permission to be present at what was strictly a private trial, and even to speak of it as we thought fit. The furnace was fettled in the usual way with ground hematite and mill scale, and was charged with 4 cwt. of remelted pig made from scrap on the works, and not very good. To improve the quality of the iron an old casting of very good grey iron, weighing about 60 lbs., was thrown in at the last moment before the door was closed at 7.15. At 7.55 the iron was all melted; at 8.3 it commenced boiling, and at 8.5 the rotary rabble was introduced. Then might be witnessed a scene absolutely without parallel in the iron trade. An elderly gentleman, in an overcoat and spectacles, proceeded to puddle a heavy charge of iron; and he did it too, part of the time, with one hand. The tool revolves at about 200 revolutions per minute, and there can be no mistake about its action on the iron. If it were possible for ten strong puddlers to introduce ten rabbles at once, and to work a charge altogether, they could not produce the same result. The rabble resting on the bottom careers all about the hearth, a turn of the wrist directing it hither and thither. The centrifugal force of the rotation keeps the rabble perfectly clear, of scale, while the thorough action of the tool could not be better exemplified than by the little flakes of iron come to nature thrown up from the cinder bath and falling back again like snow. At 8.15 the round rabble was withdrawn, the iron having been brought to nature, and the screw rabble was inserted and worked for 4 min., when it was taken out. The strap connecting the little donkey engine which drove the apparatus, with a rigger, had stretched so much that it slipped; this did not occur, however, until the work was all but complete, and the first ball was taken out at 8.32, while the last was removed at 8.47. The entire operation had thus lasted but 1 hour 32 min., while the yield of the iron was evidently very large. The balls worked under the hammer in a way which left nothing to be desired. We may conclude this article in the words of a puddler standing by and speaking to a mate: "I'm blowed, Bill, but that's what we chaps has been wanting all along." We suspect the masters will want M. Dormoy's invention quite as much as the men. We may state that among the gentlemen present during the day were Mr. Jeavons, Dr. Noad, Mr. Kirkaldy, Mr. Wright, M. Dormoy, M. Dudley, Mr. Paget, Mr. Halpin, Mr. Norris, and several others interested in the progress of the iron trade.

ECONOMICAL MARINE ENGINES.

"From The Engineer."

The moment we attempt to deal with the economy of fuel in marine engines we encounter the question—"Shall we use compound or non-compound engines? "We are unfortunately but too well aware that a single sentence written against compound engines influences certain of our readers as a read flag does a bull in a Spanish arena; but this fact is not sufficiently important in its results to induce us to refrain from alluding to a subject of considerable interest to all users of steam power. We are alway desirous of acquiring and communicating to our readers every scrap of reliable information that can be obtained concerning economical steam engines, whether compound or not; and we find in the minutes of evidence given before the Committee on Designs for Ships of War an important contribution to the literature of the subject which we cannot suffer to pass unnoticed. At the risk, therefore of encountering a very sharp and angry criticism, we shall proceed not only to reproduce the gist of the evidence bearing on economy of steam in our navy, but to deduce such conclusions from it as appear to us to be justified by facts.

The evidence may be classed under three heads:—We have first a paper—Appendix C—by Professor Rankine, entitled, "Remarks on Economy of Power in Compound Marine Engines;" we have, secondly, the evidence of Mr. J. Wright, Admiralty Superintendent of Machinery; and, thirdly, notes from Messrs. Ravenhill, Hodgson, and Co., T. and J. Rennie, Laird Brothers,

Humphreys & Tennant, Napier & Sons, and John Elder & Co. These notes convey very little information which is not already public property; we need, therefore, refer but slightly to them. Professor Rankine's paper and Mr. Wright's evidence deserve much attention, and we propose to consider both at some length. Professor Rankine may be regarded as representing the theory of the subject; Mr. Wright deals with practical questions only.

Two special advantages are claimed for the compound engine. The first is, that it equalizes the strains on the crank shaft, and consequently permits high-pressure steam to be used at sea with measures of expansion which are not available in non-compound engines. The second advantage claimed is, that in compound engines the second cylinder acts the part of a "heat trap" between the condenser and the high-pressure cylinder, and by reducing the frigorific influence of the condenser, conduces to economy of fuel. We are not aware of any other advantages usually claimed by theorists for the compound engine but these two, although there is a third of far more importance in the eyes of many practical men, to which we shall refer by and by, while, as will be seen presently, Professor Rankine claims yet another advantage, about which we shall have a good deal to say. Professor Rankine begins his paper by a very lucid and concise explanation of the action of steam in a steam engine, laying down the law that the great object to be sought in designing economical engines is to get the greatest possible quantity of work out of a given weight of steam, and he explains very clearly how this is to be done. Having dealt with the whole question of jacketing and expansion in theory, he next proceeds to deal with the use of expansion in practice, and so leads us up to the compound engine. Now, we think it is fair to assume that a paper such as this, being nearly, if not quite, Professor Rankine's latest utterance on the subject of steam engine economy, embodies the most recent conclusions at which he has arrived on the subject. Of course, we may be mistaken on this point, but until we receive a substantial correction from its author we will regard this paper as containing in a very small compass the best arguments that can be urged by Professor Rankine in favor of the compound system, which it is well known he advocates. This much premised, our readers will be the better able to appreciate the importance of the fact that our author says not a single word concerning the value of the second cylinder as a heat trap; and this is the more remarkable, because he handles the whole question of cylinder condensation in a masterly fashion. So far is he from endorsing the "heat trap" theory, indeed, that we find the following definite statement laid down: "So far," writes Professor Rankine, "as the theoretical action of the steam on the piston is concerned, it is immaterial whether the expansion takes place in one cylinder or in two or more separate cylinders." He then proceeds to explain in what the advantage of the compound engine really lies, in the following words: "The advantage of employing the compound engine is connected with those causes which make the actual indicated work of steam fall short of its theoretical amount; and also with the strength of the engine and its framing, the steadiness of its action, and the friction of its mechanism." We can bring forward further evidence that Professor Rankine abandons, or ostensibly abandons, the heat trap theory, in the fact that in a very pleasing little memoir of the late Mr. John Elder,* which we commend to the attention of our readers, a theory of the steam engine is given in many places identical with that now under consideration, and in it we have searched in vain for the most distant allusion to the heat trap theory. Whether these things are considered to prove much or little, will depend on the importance attached to the utterances of Professor Rankine. We venture to regard his silence on the subject as an efficient endorsement of the views we have repeatedly expressed, to the effect that the heat trap theory has no basis whatever in fact, and that the presence of a second cylinder can do no more to intercept the influence of the condenser than a long exhaust pipe could. In "TheEngineer" for July the 8th, 1870, we considered the whole question at considerable length, and gave then a numerical statement of the temperatures obtaining in each cylinder of a compound engine, and of the whole range of temperature in a non-compound engine, using the same measure of expansion. That statement was based on such a pressure as has been very seldom, if ever, used at sea, and it may be worth while to

* "A Memoir of John Elder." by W. J. Macquorn Rankine. Blackwood and Sons, Edinburgh and London, 1871.

reproduce it in a somewhat different form, corrected for those pressures and measures of expansion which are now most generally employed by builders of compound engines for our mercantile marine. From data lying before us, we know that a safety valve load of 70 lbs. on the square inch and a total expansion of nine times may be accepted as the maximum limit of successful general practice in compound engines. In ordinary work, 60 lbs. steam expanded five times is more frequently used by far. Now we shall not be far wrong if we assume that the expansion is equally divided between the two cylinders, that is to say, it will be expanded three times in the small and three times in the large cylinder, or nine times in all. The accompanying table shows the various temperatures at a glance:—

Initial pressure.	Initial temperature.	First terminal pressure.	First terminal temperature	Second terminal pressure.	Second terminal temperature.	Total range of temperature.
SMALL CYLINDER:						
lbs. 85	deg. 316	lbs. 28.3	deg. 247	lbs. 9 44	deg. 191	deg. 125
LARGE CYLINDER:						
28 3	247	9.44	191	3	141.6	105.4
SINGLE CYLINDER ENGINE:						
85	316	9.44	191	3	141.6	174 4

From this it will be seen that the total range of temperature in the small cylinder is 125 deg., while that in the single cylinder of the non-compound engine is 174.4 deg., the difference in favor of the small cylinder of the compound engine amounting to 49.4 deg. But it is to be borne in mind that the steam, in doing work in the low-pressure cylinder, has to undergo a second cooling, the range of temperature being in the large cylinder 105.4 deg. To all intents and purposes we may regard the steam as being worked in two distinct engines. If the cylinders be unjacketed, a certain amount of condensation proper to the difference in temperature between the metal and the steam, and to the weight of metal heated, will take place. Only so much steam can be discharged into the second cylinder as is left after this condensation and that due to the performance of work has taken place. In the second cylinder we have a second and totally distinct condensation; and, arguing in one way, and from one point of view, it would be quite fair to assume that the range of temperature in the compound engine is represented by the sum of the ranges in the two cylinders, or in the case we have cited by 230.4 deg. We shall not accept this proposition, however, because it does not accurately represent the theory of the influence of the cooling action of the exhaust from cylinder to cylinder, or from cylinder to condenser. But we wish to point out, first, that the large cylinder alone of the compound engine is larger, weighs more, and presents a greater cooling surface to the incoming steam than the single cylinder of the non-compound engine; and this fact, by itself, would be enough to blow the whole heat trap theory to the winds as an exploded delusion; but even this argument need not be weighed. All compound engines made in the present day have jacketed cylinders; and the fact is that, with jackets, the range of temperature in the metal of the cylinder is extremely small, and, as a consequence, no heat trap is wanted. It may be urged that we simply transfer the waste from the working steam to that in the jacket; but this is not strictly true. When the cylinder or cylinders are without jackets the working steam becomes extremely damp, and in that condition acts as an admirable conductor of heat; but this is not the case when jackets are used, the steam being then too dry to carry off much heat. It may be accepted as an axiom, that when an engine is fitted with proper jackets it is a matter of no importance whatever whether it is or is not compounded, so far as the prevention of cylinder condensation is concerned. Of the two, the balance of advantage will be in favor of the non-compound engine, because a smaller weight of metal will be exposed to the influence of the exhaust in it than can be the case in a compound engine of the

same power. Whether Professor Rankine does or does not accept our opinions as correct so far, and argue as we have argued, we are unable to say. Here, at all events, is the fact, that neither in the "Evidence Appendix" nor in his memoir of Mr. Elder does he make the least allusion to the use of the second cylinder as a heat trap. He does, however, as we have stated, claim a very important advantage for the compound engine, of which very little has been heard till recently, and what this advantage is we shall now proceed to consider.

We have shown that Professor Rankine states definitely that theoretically it is a matter of no consequence whether steam is expanded in one cylinder or in several cylinders, and that he makes no allusion either in the paper under consideration, or in his memoir of Mr. John Elder, to the heat trap action of the low-pressure cylinder, for which so much was claimed before the true theory of the steam jacket was fully understood. Apparently abandoning nearly all other grounds for his advocacy of the compound system, Professor Rankine now boldly comes forward with the statement that its true value is to be found in the fact that the compound engine, properly constructed, has less friction than any other form of steam engine habitually used; and he goes on to explain the grounds of this belief at great length. We have the utmost possible respect for Professor Rankine's scientific attainments, yet we confess that, holding the opinions we do, we have no other course open to us than to join issue with him at this point, and dispute the accuracy of his deductions; and here we must, to avoid all chance of conveying an erroneous impression, quote our author's own words:—

"A subject which at one time was almost wholly neglected, and which even now does not always meet with the attention that it deserves, is, the diminution of the friction of the engine, by causing the forces which drive the shaft round to balance and neutralize as far as possible each other's actions on the bearings where the friction takes place. As an elementary illustration of this subject: suppose that a shaft is made to rotate by means of a single force applied to a single crank pin. The whole of that force will be transmitted to the bearings, and will there produce a pressure which will cause a certain amount of friction in addition to that produced by the weight of the shaft. But if we now divide the force required to drive the shaft into two equal forces, each of half the amount, and apply them in opposite directions to a pair of cranks exactly opposite to each other, those two driving forces will balance with each other as regards pressure on the bearings, and the friction will be that due to the weight of the shaft alone. It is impossible in practice to realize this balance of driving forces with absolute precision; but an approach to it can always be made. One of the most important advantages of compound cylinder engines with opposite cranks is their enabling that balance of driving driving forces to be approximately realized; and that advantage had been neglected, or very imperfectly developed, before Messrs. Randolph and Elder constructed their marine engines, which in this respect were a great improvement upon all compound engines previously invented."

Now we have no intention of disputing that in this statement there is a large proportion of truth, but a glance will show that it does not contain a complete statement of the case. In the first place, it is not necessary to secure the required diminution of frictional resistance that we should use compound engines. The proposition applies to any form of multi-cylinder engine in which the forces are made to act simultaneously at opposite sides of the crank shaft; but this is not all: the friction of an engine is not all concentrated in the crank shaft bearings. Whatever the number of cylinders used, the sum of the friction of the crank pins in the big ends of the connecting rods must be the same in theory, while in practice it is certain to augment slightly with each increase in the number of bearings. As regards the friction of the crossheads in the guide bars, precisely the same truth applies; when we come, however, to deal with the frictional resistance of all packed joints, such as those of stuffing-boxes, pistons, etc., we find that there is a considerable increase of friction caused by multiplying the number of cylinders. In ships, again, it is certain that the thrust of the shaft will be the same, other things being equal, whether we use one cylinder or half-a-dozen; and it follows as a consequence that the only saving of friction to be had from balancing the strains must be referred to the crank-shaft bearings, and to them alone; and we venture to hold that in a six-cylindered engine the friction proper

to the additional pistons, joints, etc., must be greater than any saving effected as regards the crank-shaft bearings. Builders of racing portable engines have exhausted every known scheme for reducing friction, but we do not think there is a builder in the kingdom who would use two cylinders working on opposite cranks with a view to reduce friction still further. Professor Rankine, however, does not content himself with theories, he brings forward facts. To prove that his arguments are sound, he recounts and considers at much length the results obtained from the competitive trial of H. M. S. Arethusa, Octavia, and Constance, the first fitted with trunk engines by Penn, the second with three-cylinder engines by Maudslay, and the last with six-cylinder engines by Elder. It so happens that nothing is better known to naval engineers than the fact that the race of these ships to Funchal in September and October proved little or nothing. However, our author gives figures from which he deduces that "at the same speed the Octavia would require 27 per cent. more indicated power than the Constance, or the Constance 21 per cent. less power than the Octavia." The Constance was driven at 8.8 knots per hour by 1,747 indicated horse-power, while the Octavia was driven at 7.52 knots by 1,400 indicated horse-power, and the proportionate efficiency of mechanism is given by our author as 100 : 127, or as 79 : 100. He, having stated thus much, goes on to use the following remarkable words: "The superior economy of fuel as compared with indicated power in the Constance is of course to be accounted for by a higher initial pressure and a greater rate of expansion than those used in the other vessels, combined, possibly, with better jacketing and greater superheating. But the superiority of the Constance over the Octavia in efficiency of mechanism—in other words, in economy of indicated power, as compared with effective power—can be accounted for only by the comparative smallness of the friction in the engines of the Constance; and when it is considered that the engines of the Octavia were of good design, and of the best possible workmanship, the comparative smallness of the friction in the Constance must be ascribed mainly, if not wholly, to the balance of driving forces—the result of the arrangement of opposite cranks in Mr. Elder's three-cylindered compound engines." Let us put this statement in another form. We have seen that the only advantage as regards reduction of friction proper to the Elder system concerns the crank-shaft, and it alone. Now, if the Octavia required 27 per cent. more power to drive her at a certain speed than the Constance did, it is evident, from what has gone before, that this 27 per cent. must have been needed to overcome the friction of the crank-shaft in its bearings, if we suppose that the crank-shaft of the Constance revolved without friction. Let the fixed speed be 8.8 knots. The Constance required 1,747 indicated horse-power to attain this speed; the Octavia would require 27 per cent. additional, or 470 +1,747=2,218 horse-power; and of this no less than 470 indicated horse-power—or, say, 21 per cent. of the entire power developed—would be expended simply in overcoming the friction of the crank-shaft in its bearings. Be it remembered, however, that the Octavia had three cylinder engines, with the cranks disposed at angles of 120 deg. The forces must, therefore, have been very nearly as well-balanced as in the case of the Constance. Under the circumstances, we find it extremely difficult to accept Professor Rankine's conclusions, in the light of our present stock of information on this point, as being accurate. Even, however, though all his arguments in favor of the double three-cylindered engines were perfectly conclusive, it is evident that they would apply equally well to non-compound engines.

We have now to deal with Mr. James Wright's evidence. The minutes of this evidence occupy 5½ large pages of close print, but we find that the questions of the committee take up more space than Mr. Wright's answers. We rise from the perusal of these minutes with the impression that Mr. Wright is an extremely cautious witness, who takes special care not to make a statement unless he is perfectly sure of his ground; and we attach the more value to what he has said, as a consequence. Mr. Wright does not halt between two opinions; he believes in the compound engine, and he advocates its adoption in the navy. But the moment we proceed to sift the reasons why he advocates it, we come across the fact that he has really little or nothing to say in its favor; on the contrary, nearly all the evidence that he adduces concerning the results obtained, so far, from compound engines in the navy, is damaging to his cause. The second question put to him runs thus: "Have you had any experience of the

relative conomy of compound engines and simple engines at sea?" To which he replied: "Our experience is not very definite upon that point. We have been making some experiments lately with compound engines, but we have not very distinct experiments with the other engines with which to compare them." Then follows a series of questions and answers concerning the engines of the Sirius, Briton, and Tenedos, which contains nothing worth notice except that the lowest coal consumption realized appears to have been about 2 lbs. per indicated horse power. Asked as to the comparative weights of compound and non-compound engines of the same power, Mr. Wright replied that the weight of the compound engine was from 5 per cent. to 10 per cent. greater than that of the simple engine. He was then questioned as to the probable durability of the compound engine, and replied that as far as his experience went it was not favorable in this respect to the durability of engines on the system working at 30 lbs. on sq. in., and he cited the engines of the Crocodile and Serapis troopships as an example. We have already told our readers that as a consequence of the incessant failures of the compound engines in these ships they were taken out altogether, and replaced with new engines of simple type. We now come to a rather important question and answer. We have all along urged that the economy of fuel said to be proper to the compound system, and to it alone, was really due to the fact that compound engines used steam of much higher pressure than the simple engines with which they were compared. If a compound engine is more economical than a non-compound engine at one pressure it ought to be so at all, so long as the rates of expansion remain the same. Now the compound engines of the Crocodile and the Serapis gave certain results as regards economy with 30 lbs. steam, and these results ought to have been better, if there is anything in the compound system as regards economy of fuel, than those obtained from the non-compound engines by which they were replaced. Mr. Wright, being asked if the new engines were "not compound," says: "No; I may say, so far as we can see from the records kept on the ordinary passages, that there is very little difference in the economy now and before in the Serapis and Crocodile." This we submit is a direct confirmation of the truth of our arguments, and Mr. Wright, although he advocates the use of compound engines, is, we are happy to see, at one with us on this point. He next estimates that a saving of 20 per cent. in fuel over the best existing engines of the ordinary type in the navy could be effected by the adoption of the compound system, and he arrives at this conclusion from an examination of the results obtained with the non-compound trunk engines of the Hercules on the one hand, and with the compound engines of the Briton on the other. Mr. Lloyd asked him: "In comparing the economy of the Briton's engines with those of the Hercules, they used 55 lbs. of steam against 30 lbs.?" Mr. Wright replied in the affirmative; whereupon Mr. Lloyd asked: "Do you not think that the difference in pressure might account for a good deal of the economy?" "Yes, certainly," replied Mr. Wright.

So far it will be seen that Mr. Wright holds opinions precisely identical in many respects with our own. Before proceeding further we must stop here for a moment to explain a point which may not be fully understood. A great many engineers maintain that the compound engine working with a given pressure and measure of expansion must be, and is, more economical in right of the principle on which it is constructed than a non-compound engine. We know that a few engineers comprehend the state of the case more accurately, and understand that the only advantage to be gained from compounding lies in some reduction in the maximum strains to which the moving parts are subjected under certain conditions. But these gentlemen do not constitute anything more, we fear, than a small minority, and the principal object we have in view in writing these articles is to endeavor to overset the fallacious theory of the majority by showing them that there is no evidence to be had in favor of the opinions that they hold; if every engineer understood in what the only advantage possessed by the compound system lay, these articles need never have been written. We find it advisable to make this explanation, because we have on the one hand been accused of being unable to understand the advantages accruing from the use of high-pressure steam and large measures of expansion at sea, while on the other hand we have been taken to task for arguing against a belief which we have been assured has no existence. So much premised, we can

return to the remainder of Mr. Wright's evidence.

Mr. Lloyd asked him a crucial question: "Have you formed any opinion as to the cause of the great economy which is said to be obtained in the double cylinder engines as compared with the engines which expand very considerably, assuming the pressure of the steam to be the same and the degrees of heating to be the same?" Mr. Wright, says, in reply: "The only cause I can see is, that the variation of the temperature of the cylinders is much less in working the steam in two cylinders than it is in one. For instance, the steam on entering the large cylinder goes in at a considerably reduced temperature, as compared with the temperature of the condensers, than it would in working the steam in one cylinder only. You would have a much greater difference between the condensation temperature and the maximum steam temperature with a single cylinder engine than with a compound engine." In this reply we have the entire heat-trap theory with which we dealt last week in a nutshell. A very few minutes after this reply was given, Professor Rankine, as a member of the committee, began to question Mr. Wright, and among his questions we find the following very significant one. Alluding to Mr. Wright's application of the heat-trap theory, Professor Rankine said: "If you had a non-conducting cylinder, I suppose the compound engine would not have the sort of advantage you are speaking of?" To which Mr. Wright replied, "Probably not." If he had said, "Certainly not," he would have been more accurate. We shall not stop to say much more concerning Mr. Wright's notions, but we may cite his replies so far as proving that there are engineers who believe that the compound engine possesses a special element of economy, and Professor Rankine's question as showing that he does not endorse Mr. Wright's expression of opinion. We shall not now go into any consideration of the relative influence of large and small masses of iron and various temperatures of admission, cut-off, and exhaust, although it can be shown that if steam is to be expanded in an unjacketed engine, the more cylinders we expand it in, the worse the result we shall obtain. It will suffice to refute the whole heat-trap theory to say that it is based, from first to last, on the assumption that considerable changes take place in the temperature of the metal of the cylinder. If an assimilation of the temperature of the cylinders to that of the exhausting steam does not occur, then the intervention of one cylinder or of 20 cylinders between the first cylinder and the condensers must be a matter of utter indifference. Now, if an engine is properly jacketed, no such assimilation can take place. The cylinders will always be hotter than the steam within them—in other words, they will be in the same condition as though they were made of non-conducting materials. If, on the other hand, they are not properly jacketed, then Mr. Wright may rest assured that the condensation in the second cylinder alone will be greater than it would have been in the single cylinder of a non-compound engine working up to the same power as the combined cylinders which he advocates. Any practical engineer will tell him that if he really wants to waste steam, the best way to set about it is to work it with a high measure of expansion in a non-jacketed compound engine.

Professor Rankine endeavored to get forth from Mr. Wright a confirmation of his own theory as to the cause of the economy, or assumed economy, of the Constance, engined by Messrs. Elder, in which attempt he was specially unsuccessful. "Have you considered," asked Professor Rankine, "to what extent a compound engine will save friction independently of the saving of fuel per indicated horse power?" Mr. Wright stated that he "was not prepared to give a reply on that point, but I should not think it would be very much if working with the same pressure and temperature of steam in each case." Further on, Professor Rankine asked the witness: "In connection with the trials of the Constance, Octavia, and Arethusa, was there not reason to believe that the Constance had a considerable advantage over the Octavia in the shape of saving friction?" To which Mr. Wright replied in a very matter-of-fact fashion: "I cannot give you an answer to that question from facts, but my impression is that the friction was considerably more in the engines of the Constance than in those of the Octavia; the Constance had six cylinders and many moving parts." So far it will be seen that Mr. Wright had proved anything but a satisfactory witness as far as Professor Rankine's theory of the Constance was concerned, but he proved yet worse a little further on. After asking two or three questions of small importance, Professor

Rankine said: "I believe I am right in saying that the returns show that the Constance was driven at the same speed with a less indicated power; what do you ascribe that to?" "I should rather be inclined," said Mr. Wright, "to ascribe it to the difficulty of ascertaining the indicated power with sufficient accuracy to form a conclusion upon the subject. I believe those ships (the Octavia and Constance) are identical." Professor Rankine did not press Mr. Wright further on this point. Our own convictions regarding the Constance are that Professor Rankine has been supplied with incomplete or inaccurate information concerning her performance on the trip to Funchal. In the first place, not a word is said concerning the cleanliness of the hulls of the Octavia and the Constance, though the point is of great importance—not concerning their trim, nor concerning the pitches and areas of the screws by which they were propelled. But apart from this, all Professor Rankine's arguments in favor of the Constance are based on the belief that screw-shaft friction was reduced to a minimum by direct balance of forces. As a matter of fact, however, such a balance of forces did not exist, at least on the measured mile trial. It could of course only occur when the power developed in each of the low-pressure cylinders was half that developed in each high-pressure cylinder, and this was not the case when, as we have said, the ship was tried at the measured mile. We feel certain that if Professor Rankine knew as much about the engines of the Constance as was known by those who had charge of them, he would never allude to them as constituting a desirable type of marine engine. During the only commission of the ship, the engines failed more than once at critical moments; and a very good authority states, "That an ordinary amount of steaming must have condemned them to the scrap heap." Indeed, it is quite evident that however strongly Mr. Elder believed in 6-cylinder engines he could scarcely find any employer of steam power to endorse his opinions. We find at pages 230, 231, and 232 of the Minutes of Evidence we are considering, a list of all the ships engined since 1854 by the firm of Messrs. John Elder & Co. This list includes 81 screw steamers, of which 15 were fitted with 4 cylinders, 65 were fitted with 2 cylinders, and one only, the Constance, was fitted with 6 cylinders — the British Government being, we presume, better able to pay for the experiment than our great steamship companies. Of paddle steamers, Messrs. John Elder & Co. engined 25, only one being fitted with 6 cylinders, and she is only of 60-horse power nominal.

HEAVY GUNS.

From "The Engineer."

The offensive force of the Glatton being limited to two 25-ton guns, and that of the Hotspur to one similar gun, the endurance of these weapons is a matter of vital consequence to ships so armed. It appears, however, that these 25-ton guns have never been subjected to such a trial of endurance as would naturally occur in any well-contested naval action or bombardment. All naval artillerists are familiar with the fact that rapid continuous fire causes a high temperature in the gun, greater and more rapid consumption of powder, unequal rate of expansion of the two metals of which the gun is constructed, and a greater initial velocity, whereby the projectile is more violently ejected from the bore. As the shot is balanced on two studs, and has to conform itself to grooves with ever-varying curves, offering an increasing resistance at the muzzle, the wriggling hammering action which abrades and indents the bore in *slow* firing, is naturally increased by rapid, continuous fire. If the lower groove be not split by the blow of the bottom rear stud, or the upper groove by that of the front upper stud, the wearing away of the edges of the grooves would facilitate their being overridden by the studs, and the gun might be expected to be disabled in the usual way at a much earlier period. The life of the 25-ton gun is officially limited to 100 discharges of reduced charges of powder of 85 lbs., mis-called "battering" charges, fired with intervals of days or weeks between every few rounds. But we understand that the Admiralty are

considering the propriety of firing these 100 rounds from one gun in a single day's practice with several degrees of elevation, so as to assimilate the exercise to that of a naval engagement. As the immense turret ships Devastation, Thunderer, and Fury will each be dependent on four 35-tons, for their offensive value, it is to be hoped that the Admiralty—remembering how 68 rounds of slow firing with pebble powder injured the only one so tried—will order a 35-ton gun to be put through a similar course of rapid continuous firing as soon as one is delivered into their hands. Such a trial by independent naval artillerists will, we trust, overturn the untenable fiction that the service guns are destroyed by the direct action of excessive powder pressure, and establish beyond cavil the well-known fact, that it is the projectile, or rather the vicious system of rifling it, which so abbreviates the longevity of English guns.

The recent arrival of the Bellerophon from Gibraltar has enabled us to inquire into her alleged disarmament by the action of projectiles fired at targets from her 9-in. 12½-ton guns. One 12½-ton gun has opened slightly in the outer coil on the chase about 12 in. from the muzzle, just where the increasing spiral offers the maximum of resistance to the escape of the shot. But the interior steel tube is uninjured. Another similar gun has given way in like manner about 2 ft. 6 in. from the muzzle, the interior steel tube being also uninjured. In two other guns the steel tube stands out rather beyond the iron jackets, whether from the increasing spiral drawing the tube out, or from the outer coils being set back, is not very clear. This disintegration appears to have given rise to unnecessary alarm, as the separation of the coils is of no great consequence, the transverse strength they are intended to impart being unabated. Still the fissures have an ugly look, and, taken in connection with the 12½-ton gun in this ship being so damaged in its rifling in 1869 as to require removal to the Royal Arsenal, and two others in 1870 being severely injured, one by the projectiles and the other by corrosion, we can well understand the faith of officers and men being somewhat rudely shaken. It is satisfactory, however, to know that the few discharges these guns have been subjected to in the ordinary course of training the crew, have not been so destructive as was at first reported.

Old and New Ideas in Astronomy.—Theories have been advocated respecting the celestial bodies during the last few years, which, new though they seem, and new as the evidence certainly is on which they have been based, will yet be found in germ, and sometimes sufficiently well developed, in the works of former astronomers. The theory that the globes of Saturn and Jupiter are as heated as red-hot iron, was advanced by Buffon and entertained by Bailly. The theory that the sun was surrounded by a perpetual aurora was advocated by Sir W. Herschel. Mairan and the elder Cassini held that there is a connection between the frequency of sun-spots and the occurrence of terrestrial auroras. Cassini also held the theory that the zodiacal light (which, by the way, astronomers would do well to call simply the zodiacal) is caused by multitudes of minute cosmical bodies travelling round the sun. The younger Cassini believed the rings of Saturn to be formed of multitudes of discrete satellites as the sands on the sea shore for multitude. The theory of star-drift was not indistinctly hinted at by the elder Herschel, while the theory of star-systems subordinate to the galaxy was suggested by Lambert and strongly supported by Michell—Michell, that most unfortunate of scientific thinkers, who mathematically demonstrated the existence of binary star-systems, the credit of which discovery adds to the already sufficient fame of Sir W. Herschel—Michell, who devised and constructed the very machine for weighing the earth, the credit of whose invention all our text-books award to Cavendish. We might cite other instances, but these will suffice to show with what good reason the students of astronomy in our day might say with Shakspeare:

> "If there be nothing new, but that which is
> Hath been before, how are our brains beguil'd,
> Which laboring for invention bear amiss
> The second burthen of a former child!"

Near Mill Spring, Wayne Co., Mo., there has been discovered a bed of oolite of great thickness, much of it occurring as a hard flint, and in other portions of the formation intermixed with and taking on the form of a brilliant quartz, showing no presence of lime whatever.

ON THE USE OF THE MAGNETIC NEEDLE IN MINERAL EXPLORATIONS ON LAKE SUPERIOR.*

By MAJOR T. B. BROOKS.

As the instruments employed in these observations are quite different from those used in Terrestrial Magnetism which are described in the works on Magnetism, a brief account of them will be given.

The Dip or Miner's Compass is a circular brass box $3\frac{3}{4}$ in. in diameter and $\frac{3}{4}$ in. thick, having a circular glass on each side, which permits a perfect view of the needle. The needle is $2\frac{7}{8}$ in. long, weighs $13\frac{3}{4}$ grains, and is counterpoised so as to stand horizontally where there is no local attraction, and where the needle is permitted to swing in a north and south vertical plane, which is the position in which it is ordinarily used. The axis of the needle is of hard steel, its points resting loosely in conical cavities in agates, fixed in two arms projecting from the side. Outside is a ring for supporting the instrument when observations are made, so placed that the weight of the suspended instrument brings the zero line of the graduated circle to a horizontal position. Although designed to be used chiefly for determining dips or inclinations of the needle due to local influences, it answers passably well for taking magnetic bearings when laid on its side, and was frequently used in this way in rough work.

As there is usually no means of throwing this needle off its points of support, the wear is great, and the instrument is often out of order. A person going out of the way of shops where repairs can be made, would do well to take two, and then have the means at hand for making ordinary repairs. The compasses generally possess each an individuality of its own, and one must know his instrument before placing much confidence in his results: they will seldom reverse, 30 deg. difference in the two readings being not infrequent. A New Jersey iron explorer informed me that his Dip Compass always indicated 90 deg. when faced west, and the real dip due to the local attraction when faced east. He is said to have used one position in buying and the other in selling iron lands, very successfully.

My compass was made by Messrs. W. & L. E. Gurley, of Troy, N. Y., but I have since seen one made by H. W. Hunter, Esq., of N. Y., which I like better. A reliable dip compass is a desideratum.

This is exclusively a hand instrument, and has no support; nearly all the magnetic observations recorded in this paper were made on instruments held in the hand. This may seem rude and unscientific to precise observers of physical phenomena; but it was found by trial that the average error by this mode of observation was less than 3 deg., which was comparatively small in localities where changing the position of the instrument only a few feet often made 50 deg. difference in the direction of the needle, and deviations of 180 deg. from the normal direction were common. It is not necessary to observe the direction of the wind to the degree to construct a useful theory of storms. Had the accurate instruments and precise methods of terrestrial magnetism been employed, not more than 50 stations could have been occupied with the time at my disposal, while with my rude methods over 1,000 stations were observed at.

The miner's compass above described is now in very general use in the magnetic iron regions of the United States. The object here sought is to endeavor to point out new and perhaps better modes of using that instrument in finding iron ore, and incidentally, too, if it has any place in general geological field work. I have long believed that the magnetic needle can be so used as to give more definite information regarding magnetic ores and rocks than has yet been done to my knowledge. I did some rude and incompleted work in this field, at the Ringwood Iron Mines and elsewhere in New Jersey and Southern New York, the results of which are in part published in Prof. Cook's Report on the Geology of New Jersey. The observations of Prof. Cook and Dr. Kitchell on the magnetism of the iron ores of New Jersey, and the use of the magnetic needle in finding them, possess interest; see pp. 532–538 of their report. The map of the Ringwood Iron Mines, accompanying that report, exhibits a part of my own observations above referred to.

The idea of applying Magnetic Science to Geology is not at all new; years ago

* From a paper read before the American Philosophical Society, Philadelphia, in April, 1872. The facts given were in part collected under the auspices of the Michigan Geological Survey.

Bischoff, after citing numerous observations that had been made in various parts of the world by different observers in regard to the influence of mountains on the magnetic needle, concluded as follows: "Assuming that it is magnetic ore alone, either as masses or disseminated through the rocks, to which the magnetic influences are to be ascribed—and in my opinion this is quite unquestionable—it would seem that magnetic observations instituted with the same degree of care as those made by Reich, would be well adapted for the discovery of hidden beds of magnetic iron ore. Such observations might therefore prove eminently serviceable to the iron industry. Certainly it would be requisite first to ascertain whether mountain masses containing only disseminated magnetic iron ore, but extending over a considerable surface, would not produce as great an effect as beds of magnetic iron ore. Sabine's observations do not appear to favor this; but, however this may be, the magnetic needle indicates the presence of magnetic iron ore where it cannot be recognized mineralogically, and demonstrates the very general distribution of this mineral."

My mode of observing was as follows: To determine "variations" east or west, the bearings of a standard line were taken as in ordinary surveys. Sometimes a solar compass was used, but oftener a pocket compass. The variations as shown by the miner's compass, termed "dips," were observed on this compass held in the hand generally in the plane of the meridian, hence the instrument would face east and west. Sometimes observations were made with the compass held at right angles with this position; that is, facing north and south, the instrument being always held in the hand and levelled by its own weight.

The intensity of the magnetic force for the three positions of the compass above designated, was measured by the number of vibrations made by the needle in a unit of time, usually taken at ¼ of a minute. The vibrations varied from zero to 60 in this time, 6 being the normal number due to the earth's influence. No attempt was made to eliminate the earth's attraction by neutralizing it with a magnet when the observation was made, or by computation. Of course, when the compass faced north or south, this was partially accomplished, because the earth's attraction would then be nearly in the direction of the axis of the needle. It must be borne in mind that the great amount of friction in this form of compass renders the number of vibrations only a rude approximation to the number which would be indicated by a delicately mounted needle.

There is no better instrument for observing variations accurately than Burt's Solar Compass; but it is too heavy for explorers' use. I have found a convenient substitute for rough observations in the Pocket Dial Compass, which, used with a watch indicating local time, is rapid and sufficiently precise. This instrument or the ordinary sun dial can also be used for running lines where there is no local attraction; for rough work I have used it instead of the Solar Compass.

I hoped to have made some observations with properly constructed instruments, such as are used in determining the elements of terrestrial magnetism, in order to institute a comparison between accurate results and my own rude work; but the nature of such investigations requires more time than I have thus far had at my disposal. Fortunately, Dr. John Locke made complete magnetic observations at several points in the Marquette Iron Region, which are recorded in "Smithsonian Contributions to Knowledge," vol. 3, pp. 25–27. One station was over magnetic rocks in Section 18, Town 47 north, Range 26 west, the geology of which he thus describes: "A loadstone in place broken into sharp angular fragments; here were two poles, 17.67 ft. apart, one attracting the north, the other the south pole of the needle." Dr. Locke found the dip to be 42 deg. 53 min., when it should have been about 76 deg. The duration of 500 vibrations was 822 sec., when it should have been about 1,500 sec., and the calculated horizontal intensity was more than four times the normal force computed for that station. If Dr. Locke had occupied 500 stations on that section of land, he would have obtained different results at each, often differing more from each other than the foregoing do from the normal forces.

These observations, like all recorded ones that have come under my notice, have had terrestrial magnetism as their chief object; therefore the observers have avoided the very localities which to the geologist possess the greatest interest—those where local magnetic attractions exist. Dr. Locke calls attention to the importance of magnetic sci-

ence to the geologist, and gives many interesting isolated facts bearing on the subject, particularly regarding the existence of magnetite in volcanic rocks, where it usually occurs.

Before dismissing the subject of instruments suited to magnetic surveys, I will call attention to a patent mariner's compass made by E. S. Ritchie, Esq., of Boston, in which the needle is entirely supported by a liquid having the same specific gravity, thus giving it universal motion. A needle so mounted and having the earth's attraction neutralized by a magnet, should point directly towards a local magnetic pole when brought within its influence, thus accomplishing with one observation and no calculations what requires at least two with the ordinary compass. For intensity Mr. Ritchie suggested the following mode: Time the needle from the instant of its being let off at 90 deg. to its passing the resting point. I am of the opinion that a valuable instrument for miners and explorers could be made on Mr. Ritchie's plan.

A modification of the ordinary compass has been made which accomplishes the same thing in part. The agate support is fitted to the needle by a sort of universal joint, which gives the needle a vertical range through half a quadrant in addition to its horizontal motion. The only one I ever saw was made from the design of the late Wm. J. Amsden, Esq., of Scranton, Pa., who made some valuable magnetic surveys. A pocket compass on a similar idea has lately been patented. A somewhat similar instrument has, I understand, been used for a long time in Sweden and Norway. On the same principle the ordinary surveyor's compass indicates dips rudely. At the west quarter post of Section 7, Town 46 north, Range 29 west, being on the east side of Republic Mountain, I find marked on the U. S. Survey plat: "End of needle dips ¼ in., variation 62 deg. west."

C. F. Varley, Esq., the English Electrician, suggested to me that a portable electro-magnetic apparatus could be constructed, with which might be determined the direction and distance to the pole of a magnetic rock by some simple observations and computations. An instrument of this kind would have considerable value in connection with magnetic needles, especially where the magnetic ore or rock was covered with considerable thickness of other material. In 1867 Mr. Varley, with a view to detecting electric currents, if any existed, made some observations both in the copper and iron-bearing rocks of Lake Superior; he found such currents in the mines of native copper, but none in the iron mines. The instruments employed were rude, having been extemporized on the spot. I do not know whether he has published anything on this subject or not.

Passing from the instruments employed to the field in which they were used, the following geological sketch will give a general idea of its character from the magnetical stand-point:

Rocks of the four oldest geological epochs yet made out on this continent are represented on the Upper Peninsula of Michigan; two belonging to the Azoic, one to the Lower Silurian, and one between these, of questioned age. The equivalency of these with the Canadian series has not been fully established, but the nomenclature of the Canadian geologists will be employed provisionally.

The Laurentian of the Upper Peninsula is like that of Canada in being largely made up of granitic-gneisses, but differs in containing no limestone so far as I have seen, and little, I may say practically no iron ore, and very little disseminated magnetite. Next above the Laurentian, and resting on it non-conformably, are the Huronian or iron-bearing rocks; these are called also by the Canadian geologists the lower-copper-bearing series. This series are made of several plainly stratified beds of iron ore and ferruginous rock, varying in the percentage of metallic iron from 15 to 67 per cent., interstratified with greenish tough rocks, in which the bedding is often obscure, which are apparently diorites, more or less altered; together with quartzites (which pass into marble), clay slates, mica schists, and various obscure magnesian-schists. The whole maximum thickness in the Marquette Region is not far from 5,000 feet. Pumpelly and Croedner make them much thicker farther south.

While the great Huronian area of Canada north of Georgian bay bears, so far as I am aware, little or no workable iron, and derives its economic importance from its ores of copper, the Marquette series, supposed to be of the same age, are eminently iron bearing, and have as yet produced no copper. It is doubtful if in the same extent and thickness of rocks, anywhere in the world, there is a larger percentage of

iron oxide than in the Marquette series. In the order of relative abundance so far as made out, the ores are the specular hematites, magnetites, and soft or brown hematites. These all exist in workable beds, and all as disseminated minerals in rocks usually silicious. The geological distribution of these ores of iron in the Huronian series will be considered in another place. The geographical distribution is less understood; so far there seems to be the greatest concentration of magnetic ores in the Michigammi District of the Marquette Region. From this, the relative proportion of magnetite seems to decrease as we go east, north and west, and probably south, although there is a considerable magnetic attraction in the Menomonee or southern iron region.

Next younger than the Huronian are the copper-bearing rocks of Keweenaw peninsula, which extend westward into Wisconsin, the age of which has led to much controversy; good authorities having placed them in different epochs, from the Azoic to the Triassic. Recent observations made by Prof. R. Pumpelly and myself go strongly to confirm the view, if we have not positively demonstrated it, that they are nonconformably overlaid by the Silurian, and therefore related to the Azoic. The relations of the copper-bearing rocks to the Huronian are not fully made out. In tracing the dividing line from Bad River in Wisconsin to Lake Gogebic, Michigan, last fall, a distance of 60 miles, Prof. Pumpelly and myself found them nearly, if not precisely, conformable, but widely different in lithological character.

With regard to the magnetism of the copper-bearing series, the United States Surveyors mark considerable variations in several places in the Land Office plats, due in all probability to disseminated magnetite in the trappean members of the series, although good authorities have ascribed these variations to electric currents. My own observations on the magnetism of these rocks have been limited, but lead me to believe that it is far less in amount and less persistent in character than is usually the case in the Huronian, indicating that the magnetite (to which I ascribe the attractions) is perhaps an accidental rather than essential constituent, and small in amount. Macfarlane found less than one per cent. in one of the Portage Lake traps.

The next series of rocks in ascending order are the horizontally-bedded Lower Silurian sandstones which skirt the south shore of Lake Superior, nearly its whole length, called, by Foster and Whitney, Potsdam, and assigned by the Canadian geologists, under the name St. Mary's, to a later period. They have not been proven to be magnetic, although strong magnetic attractions have been observed over this Silurian area, as will be explained hereafter.

To recapitulate, we have: 1. The Laurentian granite and gneiss, practically nonmagnetic; 2. The Huronian iron-bearing rocks, generally highly magnetic; 3. The copper series, slightly magnetic; and 4th. The Silurian rocks, without magnetism. This classification is intended to apply more particularly to the rocks of the Marquette and Menomonee regions proper, embracing the central and southern portion of the Upper Peninsula; and even here, as has been noted above, under Huronian, there are exceptions. This sketch of the Marquette rocks, in the light of the distribution of magnetite, would be incomplete, did I not mention the fact that this mineral is very generally present in the form of fine sand in the drift in the region I am describing. If one moves a magnet about in the sand of a creek it is rarely that magnetic sand will not be found adhering. I have never seen it accumulated in quantities that would point towards its being utilized; nor have I ever observed a magnetic attraction which I ascribed to the mineral in this form.

We will now return to the Huronian or highly magnetic series, taking up its structure in detail. About 19 lithologically distinct beds or strata make up the series; of these, 6 and probably 7 are so magnetic as to cause considerable variations in the needle. These beds vary from 40 to several hundred feet in thickness, and strike and dip in all directions, and at all angles. The prevailing strike, however, is easterly and westerly, and dip at high angles, often vertical. These rocks often outcrop, when we have no use for the magnetic needle in their study. Again, they are covered by deep drift, where magnetic observations or workings can only reveal them.

In order to study the magnetic characteristics of these rocks more minutely than could be done in the field, two hundred and twenty-two specimens covering all the more common varieties, were collected and are deposited in the cabinet of the University of Michigan; they are fully described in the chapter on lithology of my Geologi-

cal Report. Fifty-four or twenty-four per cent. were found to possess some degree of magnetic power as manifested by their influence on a magnetic needle; each specimen being in turn made to touch each end of a mounted needle. If it had the power to lead it 20 deg. from its normal direction, the specimen was said to be feebly magnetic, and strongly magnetic when the needle followed the specimen round the circle if held about half an inch from it. Of the fifty-four specimens, thirteen were feebly magnetic, twenty-nine magnetic, five decidedly magnetic, and seven strongly magnetic. None would, however, lift ordinary carpet tacks. Twenty-four, or nearly one-half, possessed polarity in some degree. Thirty were simply magnetic, with no polarity that could be detected by the rude means employed; in some instances the specimen would repel the needle at half an inch distance, but would attract it if placed in contact. Such specimens were rated as possessing polarity. All of the strongly magnetic specimens were rich in magnetite and possessed polarity, and it is not improbable that all would have been found to possess it if tested by more delicate means. Von Cotta, however, speaks of magnetic iron ore which had no polarity. The specimens generally attracted the south pole more strongly than the north. When examined, they had been collected about three months. Whether they would have shown more or less magnetic power if examined when freshly broken, I do not know. Dr. Kitchell says that under certain circumstances fragments gain magnetism.

In 1860 I saw a powerful loadstone for its size, in the possession of Professor Trego, of Philadelphia, which he had picked up in New Jersey twenty-two years before. I once collected a number of pieces of loadstone in the Bull Mine, New York, which in the mine would lift small nails; in a few days two-thirds of them had lost this power. This may have been due to the fact that in the mine the nails themselves were magnetic by induction.

As to the location of the poles in magnetic rocks, the laws of magnetism would make them near the surface or next divisional planes or terminations of masses. Observers are generally agreed that iron ore is most magnetic near dykes of volcanic rock. Quoting again from Dr. Kitchell, "Geology of New Jersey," p. 535: "The extent of the magnetic qualities of iron ores depends on their position with respect to the surface; the nearer to the surface the greater will be their magnetic properties. This appears to depend on the action of surface water and atmospheric agents, for it has been frequently observed that ore, when first taken out of a mine at a considerable depth, possessed but slight magnetic properties, but on being exposed to the atmosphere for a few months or years it would increase so much that excellent specimens of loadstone for experimental purposes could be selected therefrom. Seams of ore that contain numerous joints and fissures, through which water and atmospheric agents pass, possess more decided magnetic properties than those which are more compact and free from crevices and fissures."

These remarks of Dr. Kitchell possess much interest; I have made no precise observations on this point.

Classifying the magnetic ores and rocks of the Marquette Region economically, the merchantable ores, according to the present standard of richness, would not constitute two per cent. of the whole; the balance being ferruginous quartzites and schists possessing no present value as ores. The merchantable magnetic ores have so far been all found in one formation near the middle of the series, and that is not all pure ore by any means; therefore, when an ore-hunter finds an "attraction" in the Lake Superior region, the chances of his having found a mine are not more than one in fifty. Neither the strike nor dip of the formation seems to affect its magnetic power. This depends, so far a my observations throw any light on the question, chiefly on the percentage of magnetite entering into the composition of the rock. Prof. Cook—"Geology of New Jersey," pp. 537–8—says that the magnetism of iron ores was influenced by the "pinch and shoot" structure so prevalent in the iron mines of New York and New Jersey. He points out the analogy between these regular pod-shaped masses—"shoots" of ore,—pitching downward in a northerly direction and an iron bar in the same position, both become magnetic and have polarity.

The "pinch and shoot" structure, if it exists in the magnetic ores of the Marquette Region, is obscure, and in strike and dip there is no parallelism between our rocks and those of New Jersey, as is shown elsewhere. Yet our ores must usually be more strongly magnetic than those of New Jer-

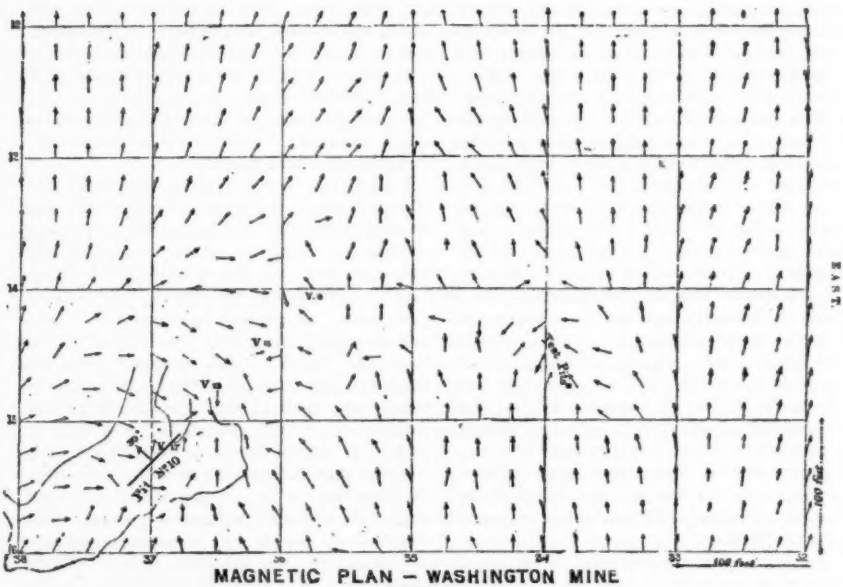
sey; for Prof. Cook says: "It is generally conceded that ore, covered by 30 ft. of earth, will attract the needle, and 'large veins' have disturbed it when covered by 50 ft. of earth." Now at five and even fifty times these distances horizontally, the needle is often deflected in the Marquette Region.

Having now described the instruments employed and mode of using them, as well as the field of operations, we are prepared to consider the results obtained, and to estimate their value to the explorer, miner, and geologist. Unfortunately, the charts which best illustrate the subject are not yet engraved, and will be so large as to prohibit their use in this form; they will appear in my geological report.

Under this head we will consider:

1*st*. Variations or deflections of the horizontal needle from its normal direction, under the influence of local magnetic attraction.

FIG. 1.



This is well illustrated by Fig. 1, which is a magnetic plan of the west end of the new Washington mine, embracing Pit No. 10. The dotted line represents an outline of the workings; the ore dips 30 deg. to the north-west.

The arrows indicate the direction in which the needle actually pointed at each station. They leave no doubt as to the approximate position of the line of maximum variation which must be over or nearly over the magnetic mineral producing the effect. The observations for intensity by vibrations, marked V. 17, V. 13, V. 11, and V. 8 (6 being the normal number), confirm the variations. The decrease in intensity toward the north-east is probably due to greater depth of earth in that direction, which removes the needle further from the ore, thereby giving the ore less power over it.

Of course, the direction in which a needle rests at any point is the resultant of all the forces acting on it, including that of the earth. If the latter be neutralized by an artificial magnet, then the needle should point toward the local pole as near as its mode of suspension would permit. If there be two or more local poles, which is the more common case, then the needle should stand between, inclining toward the greater. It is evident that there are a number of local poles in the locality represented in the diagram.

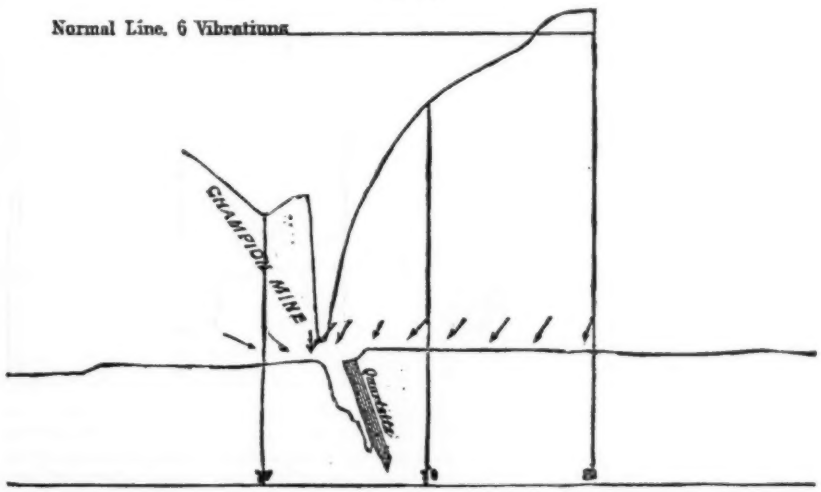
The distance to which a given local magnetic pole will affect the needle will depend, 1st, on the strength or intensity of attraction possessed by such pole; and, 2d, on the direction from the pole to the needle. If a needle be carried south of a local pole, it will not vary, no matter how strong the attraction exerted, because the earth's forces and the local force act in the *same line and same direction*. If the needle be placed north of the same pole, there will be no variation until it is so near the local pole that its force overbalances that of the earth, when the needle will turn around, causing a variation of 180 deg. If moved east or west, the local pole will exert its maximum influence, and will attract the north end of the needle toward itself in some ratio of the distance. The influence of the magnetic rocks at the Republic Mountain has been observed at a distance of 2,500 ft. horizontally.

It is evident from this that a range of magnetic ore or rock, running east and west, would produce least variation, and one running north and south, or near that direction, would produce most variation, a principle of practical value to the explorer.

If, lastly, the needle be placed directly over the local magnetic pole, it is evident that no variation will be produced, as the effect of the local pole would be entirely neutralized by the centre pin of the compass. A dip needle would, on the contrary, be most influenced by a pole so situated.

2*d*. The deviations in the dip compass, termed "dips," are well shown in Figs. 2 and 3, which represent north and south

FIG. 2.



sections across the Champion Mine deposit. The arrows indicate the actual directions assumed by the needle, when permitted to swing in a north and south vertical plane. The significance of these dips, taken in connection with the rocks shown by the geological sections beneath, is plain. Fig. 2 represents one magnetic formation—the Champion bed itself. Fig. 3 represents three magnetic formations, the richer and most highly magnetic being the Champion deposit shown in Fig. 2. An inspection of these figures, and a consideration of the laws of force, make it evident that every highly magnetic bed will present two lines when the dip will be 90 deg. One immediately over the bed and the other to the north of the first, at a point where the mechanical resultant of the earth's force urging the needle north, and the local force urging it south, balance each other in a vertical line. This northerly line of 90 deg. attraction, does not indicate ore underneath, but simply ore somewhere to the south. Considerable money has been wasted and will be wasted in the Marquette Region, from neglecting so simple a principle.

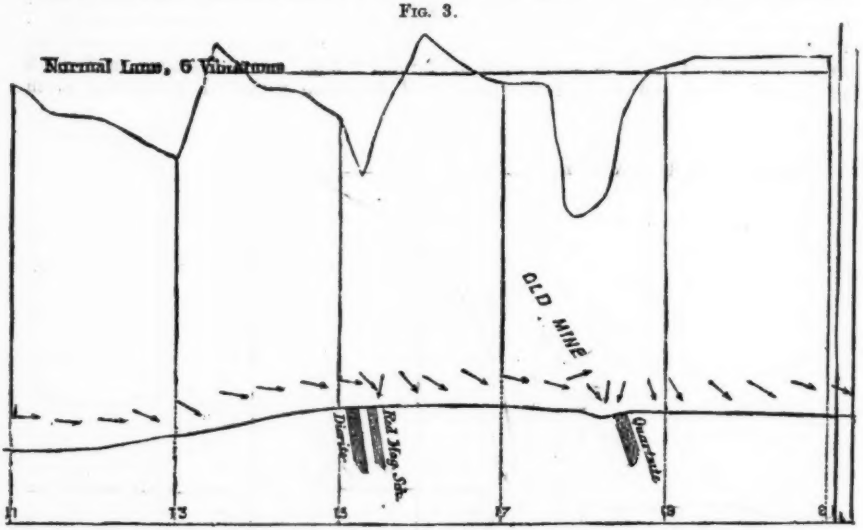
It is evident from the plan and sections

shown by Figures 1, 2, and 3, that the north end of the needle almost universally points towards the ore. This law may be more broadly stated by saying that the upper portion of any and every piece of cast or wrought iron, or non-magnetized steel, or mass of magnetite, is a south pole and the lower part a north pole.

3*d*. The relative intensity of the magnetic force resident in the rocks under consideration, was approximately measured, as has been explained, by the number of vibrations produced in the needle in quarter of a minute, as gravity is measured by the vibrations of the pendulum. The intensities as indicated by the dip compass needle on the two sections of the Champion Mine, are shown in Figs. 2 and 3 by the upper irregular curves, the ordinates of which are directly proportional to the number of vibrations.

It is a law of magnetism that its force diminishes like light, that is, as the square of the distance; which may be expressed by saying that magnetic force is as the square of the number of vibrations made by the needle in the unit of time. Therefore these curves, striking as they are, indicate far less variation in the relative force than

FIG. 3.



actually exists. Under the influence of the cosmical force alone, the needle vibrated but six times in the unit of time, which was taken at a quarter of a minute. When the dip compass was placed a certain distance north of the magnetic rocks, the curves show the vibrations to be less than the normal number. This may be explained in the same way that the northerly line of 90 deg. attraction was accounted for. For it is evident that there must be some point to the north of every mass of ore or magnetic rock, when the earth's attraction would be exactly balanced by the local force; hence at this point the needle would stand indifferently in every direction and would not vibrate.

All the observations for intensity above considered were taken at an elevation of 4 ft. from the surface. Sometimes the rocks came to the surface, sometimes there were several feet and perhaps yards of drift between; it is therefore an important practical question to ascertain what effect different elevations of the needle have on the number of its vibrations.

The difficulty of attaining any considerable elevation from which to observe intensity, renders our observations on its rate of diminution due to elevation or vertical distance of little value. The theory of the sphere of attraction and law of decrease of force, as the square of the distance from the centre, has been mentioned; but with several local forces acting on the same point (the case usually presented in nature), the law is greatly modified; the decrease being in a less ratio. This subject possesses especial interest in connection with the determi-

nation of the depth at which magnetic rocks, producing a given disturbance, will be found; therefore, the few observations made, unsatisfactory though they are, will be given. At Republic Mountain a staging was erected in the windfall, by means of which eight equidistant observations were made; the lower one on the magnetic schist, the upper one 14 ft. above; the results were as follows:

Elevation in feet.	Vibrations.		REMARKS.
	Facing west.	Facing north.	
0	56	53	On surface of schist.
2	41	41	
4	33	30	
6	27¼	30	
8	19	23	
10	15¾	24	
12	18	24	
14	12	20	

At another point near the above and over the same magnetic rock, the following vibrations were observed:

Elevation in feet.	Vibrations.		REMARKS.
	Facing west.	Facing north.	
0	60	60	On surface of schist.
3	50	49	
6	36	37	
9	25	26	
12	18½	18	

The observations have all been represented graphically, but as no law was apparent, and as the figures can be easily reproduced, they are not given. The first table gave the most regular curve, but still too angular to attempt the application of a mathematical formula. They do not seem to me to afford a basis for calculation, as to how high the magnetic influence of these rocks could be detected. I have an impression, however, without being able to give any reason, that it would be considerably less than one half mile, which was shown to be the distance to which the influence of the same rocks extended horizontally. I cannot consider it probable that a dip would occur where an earth covering of over 2,000 ft. exists, if such a case were possible. At the Champion mine, by the aid of shaft house No. 2, an elevation of 44 ft. above the ore was attained, and the following observations made:

Elevation in feet.	Vibrations.			REMARKS.
	I.	II.	III.	
0	18½	17⅛	23	Level of surface of ore in shaft.
18	19	17	17	Surface of ground.
32	16½	16½	16½	Girder of shaft house.
44	15½	..	15	Girder of shaft house.

At other points at the Champion mine, 25, 32, 33 and 40 vibrations were observed, the compass being within 5 ft. of the ore. The diminution here is quite regular and nearly as the distance. If the rate continue, the vibrations should reach the normal number (6 for the instrument used) at about 150 ft.; but it is highly improbable that this law would hold for the whole height.

The difference between the rate of diminution at the two localities is very marked; at Republic Mountain an elevation of 12 ft. in one instance reduced the vibrations from 60 to 18½, in another 14 ft. elevation reduced the number from 56 to 12. At the Champion 44 ft. elevation made an average of less than 4 difference in the vibrations. In this comparison the following geological differences must be borne in mind.

The Champion deposit at shaft No. 2 is a heavy bed of nearly pure black oxide running east and west and dipping north at an angle of 68 deg., and it is the only magnetic rock on that section. The Champion deposit loses its magnetism in going west, specular slate taking the place of the magnetite in that direction. The Republic Mountain bed over which the observations were made (No. X.*) is, on the contrary, a silicious schist, containing not to exceed 33 per cent of magnetite (the merchantable ores of Republic Mountain, of which there are large deposits, are in bed No. XIII., and are mostly specular hematites). This magnetic bed X. is associated with others of a similar character, all striking north-west and south-east and dipping nearly vertical. The specimens of these magnetic schists which were examined possessed marked polarity. The Champion deposit evidently contains more magnetite

* The roman numerals refer to the order of the beds of the Huronian series counting upward from I. to XIX.

within the same sphere of influence than the Republic Mountain.

There is no doubt that variations and dips are a much more delicate and ready means of observing slight magnetic attractions, than vibrations observed with the rough instrument employed. In one instance at Republic Mountain the dip at 12 ft. elevation was 30 deg., at 9 ft. 50 deg., at 6 ft. 70 deg., at 3 ft. 77 deg., at 0 or on surface of rock 105 deg. It appears that the magnetic poles of the Champion bed are more deeply seated than those at Republic Mountain, which seem to be at the surface. This may be due to the fact that the upper part of the Champion deposit is mined out. Sets of careful observations made for considerable heights, both for dip and vibrations, would possess great interest, especially if made over beds of ore or rock, the position and character of which were known. In a record of over three thousand magnetic observations made by me in Michigan, Missouri, New York and New Jersey, I have not in more than six instances found the needle in the dip compass above described to vibrate over 40 times in a quarter of a minute, and in no instance in which this rate was observed was the needle removed more than 5 ft. from the magnetic mineral. Of course in the same needle the vibrations will vary with the degree of magnetism that has been imparted to it, and the condition of the instrument in other respects. I have had a rude standard, and when my needle fell below that it was overhauled, so that the numbers are relatively correct. I do not remember to have observed over 15 vibrations in a quarter of a minute, or one per second, at a greater distance than 50 ft. from a magnetic bed, and usually this number of vibrations would indicate a distance not exceding 25 ft. in the Marquette Iron Region.

The facts given above, with others in my possession, enable us to answer provisionally the following practical questions:

I. Can we by means of the magnetic needle determine the order of superposition or succession of beds of the iron-bearing rocks?

Comparing the magnetic sections obtained at the Republic Mountain and Champion mine, it is evident that, while there is considerable variation in the details, the salient features agree remarkably, pointing towards the same order and same lithological character in the rocks. A number of other sections made within 10 miles of the above-named localities, across the same belt of rocks, gave the same general result.

It is therefore asserted with much confidence that where a magnetic section similar to these is found in the Michigammi district, a corresponding geological section will be found beneath the surface; and that, as a rule, there will be less difference in the magnetic sections than in the topographical, which we all know depends greatly on the underlying rocks. But whoever expects to find many places where so complete sections can be obtained as these localities afford, will be disappointed, for they present rare opportunities for studying the structure and magnetism of the Huronian series.

In places the covering of the drift will be so deep as greatly to reduce the intensity, making it exceedingly difficult to observe with ordinary instruments, as was the case at the Cannon location. Again, the lower magnetic rock, beds VI., VIII., and X., are in places far less magnetic, containing sometimes very little magnetite, as is the case south of the Washington mine. In other places the lower magnetic rocks may be entirely wanting, owing probably to a fault, as at the west end of the Champion. On the north shore of Lake Michigammi there is a magnetic bed above XIII. (the ore formation), being younger than any member of the Republic Mountain series. In other places XIII. is wanting, and when present it is sometimes highly magnetic, as at the Champion, and again it holds very little magnetite, as at Republic Mountain, the pure ore there being mostly specular hematite, as has been elsewhere observed. With all these uncertainties, the results of magnetic surveys cannot but be valuable in the exploration and development of iron properties, and in the solution of all questions of structural geology in regions of magnetic rocks. In such rocks their value to the geologist is only second to topographical work, and, considering the cheapness of magnetic surveys, they may often pay best if means be limited.

Such investigations, if made with precision, ought to throw light on the lithological character and intricacies of structure of these rocks, and on the nature of the magnetic force resident in them. This could not, however, be undertaken; the work done is more than was contemplated, and more than was justified by the means at my disposal.

II. Is it possible to determine quality—*i. e.* the percentage of iron—in a magnetite rock by means of the magnetic needle? In other words, can the needle alone make us sure we have a workable deposit of ore under our feet?

This is the most important practical question connected with this subject, and is the one constantly presented to the miner and explorer. Magnetic observations should always be made in connection with topographical and geological surveys; whether these take such names, and are based on instrumentation, or whether they be such rude work as the explorer is constantly doing, but which are as much topographical and geological as the other, and often quite as valuable. A judgment on the commercial value of a magnetic bed for mining purposes should, of course, be based on all the facts available. If nothing more was known than what the magnetic needle revealed, I would say that it was impossible to tell with certainty whether it was merchantable ore or magnetic rock which produced the phenomenon. In the Marquette Region, as has been before observed, the chances are at least fifty to one that a worthless ferruginous rock was the cause of any observed attraction. But this case never occurs; we always know something more than the needle reveals. One of the most important uses of the needle, and one for which it can within certain limits be depended on, is in tracing magnetic beds in the direction of their strike *until some outcrop*, which may give us the information sought, is found. I have in this way traced magnetic beds for many miles both in the Marquette Region and in New York and New Jersey.

Preparatory to the examination of any particular range of ore, the explorer should thoroughly study up with his own instrument the phenomenon presented at some exposed or developed part of the range. This will give him data relating to variations, dips, and vibrations, which can be used where the rocks are covered and unknown. By means of the quickness of the vibrations, or of the rapidity with which they decrease as the compass is elevated, he may judge approximately of the depth of the drift, and so of other phenomena.

III. Does the magnetic needle afford the means of determining the absolute thickness of a bed of magnetic ore or rock?

My observations do not permit an affirmative answer to this question, especially if there be much earth covering. A study of all the magnetic sections which have come under my observation indicates that, while in some instances the comparative width is plainly shown, the boundaries between the magnetic and non-magnetic rocks are not generally brought out sufficiently to warrant a definite expression as to thickness. We should expect this, because the magnetic influence is centred in the poles of the masses, and towards such points the needle tends to turn.

IV. Can we by means of the magnetic needle ascertain the direction and depth of a local magnetic pole? In other words, can we determine the thickness of rock or earth covering which overlies a given magnetic rock?

Often I think we can, with much precision, locate a point in the surface over it and determine its depth, making what may be called a *magnetic triangulation*. Proceed thus: Remote from any magnetic rocks, neutralize, by means of a bar magnet, the earth's influence on the needle of a solar compass. The needle will then stand indifferently in all directions, and will not vibrate. Record carefully the distance and position of the neutralizing magnet; the compass is then ready for use. Set it up near the magnetic pole to be determined, and fix the magnet in exactly the same relative position it had before. The earth's directive power on the needle will again be neutralized, and the needle will point as near towards the local pole as its mode of mounting will permit; mark the line indicated by the needle on the ground; remove the compass to one, or, better, two other positions, and repeat the operation. If there is no other local force to interfere, the three lines must intersect in one point, which will be directly over the pole whose position is sought. By using a dip compass in a similar manner, it is evident that the data to determine the depth, by the simple solution of a triangle, would be obtained.

A magnetic needle having universal motion, such as was described above, would evidently determine both position and depth at the same time; but a solar compass must be used to fix the position of the artificial magnet used in neutralizing the earth's face, or it may be fixed by an observation on the North Star, or from a meridian line brought in from a non-magnetic area.

V. When considering the magnetism of the rocks of the four great geological epochs

represented on the Upper Peninsula of Michigan, I observed that considerable magnetic variations were noted by the Federal surveyors, over rocks of Silurian age, which had never been observed to be in themselves magnetic. In some instances these variations had been observed over a limestone, supposed to be Trenton, and at a distance of 75 miles from the nearest Huronian, or other (known to be) magnetic rocks.

This phenomenon may be due either: 1, To the presence of magnetite in such rocks, due to local metamorphism or other cause. 2, To accumulations of magnetic sand in the drift; or 3, To the underlying Huronian rocks, which may be supposed to exert their influence up through the overlying Silurian.*

Without having made a study of any of these localities, I incline decidedly to the latter hypothesis, as embracing the known facts better than either of the others.

Should this prove true—and I hope to settle it the present season—it may lead to a novel and interesting application of the science of magnetism to some of the most important questions of geology—the determination of the thickness of sedimentary rocks by *magnetic triangulation* in places where it would otherwise be difficult to arrive at such thickness. It might also enable us to work out the structure and distribution, in a rough way, of these oldest rocks which underly great Silurian areas, which would in no other way be possible, thus throwing light on the nature of the rocky bottom of the ancient seas.

On the same principle we can, of course, trace magnetic iron belts under water. I have in many instances made very satisfactory magnetic observations from a canoe in the inland lakes of the Upper Peninsula.

The bottom of Lake Superior may be partially mapped out in the same way. Silt and sand will make no difference with the needle; it looks through everything but iron.

I have endeavored above to set forth plainly just what has been done and the results obtained, and to call attention to those principles which underlie the use of the magnetic needle in exploration for iron ores. It must be borne in mind that the time and means at my disposal were meagre, my instruments imperfect, and I had no precedent to follow.

I am persuaded that the subject is worth the attention of the explorer, miner, geologist, and physicist.

* Rocks, earth, water, and air are equally transparent to magnetic rays.

THE POLLUTION OF RIVERS BY CHEMICAL MANUFACTURES.

From "The Engineer."

The late lamented Professor Faraday was celebrated amongst other qualities for taking a poetical and imaginative purview of seemingly non-poetical things. Not bending to the dictum formally enunciated a few days ago by Professor Tyndall at the Royal Academy dinner, that whereas painters worshipped nature for her beauty, philosophers worshipped nature for her order and her truth, it was a happy faculty of the great philosopher to see in the order and truth of nature the highest attributes of beauty.

In one of Faraday's poetically discursive lectures, during which the great philosopher's imagination gave itself the very fullest license to revel without overstepping the boundaries of truth, he expatiated on the beneficence of nature in only allowing the harmless elementary bodies and their innocuous compounds to present themselves to the world in their free state, or, as the philosopher put it, "unchained." He led his audience away enthralled to contemplate what the result would have been, for instance, if the element chlorine, instead of being imprisoned and made harmless in common salt and other naturally occurring chlorides, had been allowed to pervade animal and vegetable nature in all the full power of its uncontrolled energy. Following out the idea, he passed the remaining elements one by one in review, to demonstrate that which every reflective mind soon recognizes to be the truth, viz., that in the world's economy, only those elements are met with in a free state that, like oxygen and nitrogen, carbon and sulphur, can wreak no destruction on living things.

Exactly so; but, fortunately or unfortunately, just as one's temperament predisposes him to apprehend the case, many naturally noxious things become useful when under

control; and thus it is emphatically of certain noxious elements, and compounds of elements, which man has emancipated from what Faraday termed their bondage, and without the aid of which under due control, much of our civilization would decline into the barbarism of times long gone by. Prominent amongst these noxious elements is chlorine, an element which chemists have set free from its prison house this many a long year, and without the aid of which many of the most important chemical manufactures could not be prosecuted. Without chlorine the process of calico bleaching, instead of being an operation of hours as now, would occupy weeks, or even months, as heretofore. Without chlorine some of the most refined processes of calico printing, as that of discharge for example, would be abolished; and as for the paper-makers, deprive them of the aid of chlorine, and their present means of turning to account some of the most approved paper-making materials would have come to an end. These are facts, and it may be just as well they should be maturely reflected on by those amongst British legislators who are so strenuously bent just now on the maintaining of British rivers in a state of primitive Arcadian purity, and on the well-being of fresh water fish. The problem of having your cake and yet eating it, has no more been solved than that of squaring the circle, or accomplishing perpetual motion; but certain British legislators would seem to have been taking up the problem with new hopes. To check or embarrass the prosecution of industrial art would be so manifestly opposed to British national welfare that the warmest advocate of fresh water pisciculture would not overtly acquiesce in it; but we feel assured if the desires of some gentlemen and their supporters are fully carried out such must be the inevitable result. One cannot have his cake and yet eat it. Arcadian purity of running streams is an agreeable condition to ruminate over, but, we fancy, one not possible of realization out of a non-manufacturing Arcadia. Were the unsullied purity of running water to be accepted as the condition of first importance in every locality and under every possible condition, then it will soon become evident that many other operations besides those of chemical manufacture would have to be stopped. Mining, for example, is a case in point. The wash and *debris* of almost every mineral ore is injurious to fish and to vegetation. The *debris* and wash of copper mining are especially noxious, for the reason that copper is one of the metals that tend by exposure to air and moisture to generate soluble compounds, it being an axiom in toxicology, that in direct proportion to the solubility of a thing naturally poisonous is its power to do mischief. Nobody dreams of shutting up a productive copper mine because a neighboring stream has diminished in Arcadian purity. When all has been done that can be done to ameliorate the evil the noxious balance is accepted as the inevitable, and patiently borne like many other evils for the sake of a counterbalancing measure of good. We do not deny that Parliamentary action has done excellent service in imposing salutary regulations for the conduct of certain manufactures, the bye products of which without due control are injurious. The most prominent case in point is that of the soda manufacture, the bye product (muriatic acid) of which, if liberated into the air, as it used to be liberated before the ingenious and effectual process of liquid condensation by wet coke stacked in the tall chimneys, was so fatal to vegetable life as to prove more than a nuisance—a ruin for miles around. Here was an example of judicious legislative control; but even now Parliament has not succeeded in preventing the condensed muriatic acid percolating more or less directly to the nearest accessible watercourse. However, the aërial nuisance was so great that no one now complains of the alternative. The Smoke Consumption Act also has been of some avail, though even in respect of this we are of opinion that certain special trades—that of baker, for instance—are expected to accomplish, under pressure of the Smoke Act, that which is well nigh incapable of accomplishment. So far well; but reverting to the would-be Arcadian's aims and aspirations, we do not see how they can be carried out without inflicting serious prejudice, if not, in some cases, stopping altogether the prosecution of many chemical manufactures. The condition is especially hard for the paper-makers. Without chlorine they cannot get on at all, and of all industrial arts this is perhaps the one that most of all needs for its due prosecution a profuse supply of water. It would be desirable, of course, if possible, that a stream should flow from a paper mill as free from extraneous matter as on its entrance. This, however, does not lie

within the bounds of possibility. Just as reasonable would it be to expect that the contents of a laundress' wash-tub should be as uncontaminated after a wash as before. After all, it may be as well that Arcadian enthusiasts should remember the fact, that, amongst the other purposes for which water was given to the world, not the least important or the least obviously indicated is that of a detergent. Inasmuch as annihilation is impossible, then it follows that if man, in furtherance of his legitimate needs, brings the elements from their previous lurking places and makes them work, when the work is done he must dispose of them somewhere, all Acts of Parliament notwithstanding. In the great majority of cases he has only the choice of two modes of disposition—air and water. Of the two, it admits of demonstration that water is most eligible. Better of the two, that fish should sicken or even die than the lungs of man should be diseased and vegetation perish.

THE MANUFACTURE AND WEAR OF RAILS.

(*Continued from page 95.*)

Mr. H. Conybeare was of opinion that the section of a rail materially affected its duration, and that this was especially the case as regarded the design of the head and of the upper surface or wheel-track. It was obvious that each portion of the rail had its special and definite functions and conditions to fulfil, and a careful consideration of the character of these should supply rules that would regulate with certainty the contours and the dispositions and scantling of the metal in every portion of the section, that would best conduce to the fulfilment of such conditions.

Some years ago, having occasion to design the rails for Irish and Welsh railways, he had collected, with a view to determine the best form of rail, all the sections he could obtain from the Welsh iron-works, and the London metal-brokers; and he compared and collated these with a view to ascertain the extreme range of the variations in practice, and the limits of economy and practicability in manufacture. He also calculated the strain to which each portion of the section was subjected, and considered the conditions it had to fulfil, and the extent to which these conditions were complied with in each example. Having done so, he endeavored to establish definite rules which should fix absolutely the contour and the proportionate scantling of every portion of the rail section. These he had since carried out in practice, and the results arrived at were exhibited in the following diagrams and Tables. It would be seen that the diagrams, though also applicable either to the T rail or the double-headed rail, referred more especially to what was known as the Vignoles section. Everywhere except in England the double-headed section and the chair road had long been obsolete, and he thought it was much to be regretted that it was not so in this country. It was obviously essential to the perfection of any system of permanent way, that the jointing of the rails to each other, and the mode of attaching the rail to the sleeper, should be of such a description as to insure absolute uniformity of gauge and of cant, and such as to admit of no jar, shake, or movement, which might loosen the fastenings, and thereby induce hammering and concussion, which must conduce to the disintegration of the bearing surface of the rail, and to the injury of the rolling stock; and judged by this canon, a Vignoles rail, directly fastened by fang-bolts into beds planed by machinery, in rectangular sleepers, was as superior to a road in which chairs intervened between the rail and the sleeper, as the best road of the latter description was to the old stone sleepered and unfished chair road. As regarded the weight of the rails, it was possible to make them too heavy; for modern rails failed, not through their deficient strength as girders, but through the deficient homogeneity and hardness of texture in the bearing surface presented to the rails, which induced the lamination and hammering out of such bearing surface under the concentrated pressure and violent impact of the wheels. It was essential that the rails should possess an amount of vertical stiffness sufficient to confine their deflection under the passing load within unobjectionable limits. But any weight or vertical stiffness in excess of what would suffice to fulfil this condition was absolutely injurious; for as a certain amount of elasticity was essen-

tial to the durability of the rails, an excess of rigidity invariably tended to destroy the rail surface, by acting as an unyielding anvil placed beneath it, between which and the hammering action of the driving-wheels the bearing surface of the rail was rapidly beaten out into laminæ, and so destroyed; and the heavier the anvil the more rapid was the process of destruction. If extra weight and speed of traffic were to be provided for, improved quality in the material was required rather than increased quantity,—a harder surface, not heavier metal.

Thus the rails most remarkable for their longevity had been also most remarkable for their abnormal weakness and deflectibility as girders; for example, a length of 25 miles or 30 miles of the original permanent way of the South Western Railway consisted of a 75 lb. rail, laid on transverse sleepers 5 ft. apart from centre to centre. The strength of such a rail as a girder was therefore only equal to that of a 57¼ lb. rail laid on 3-ft. bearings; and as, according to Barlow's experience, the deflection of the same rail, when supported on 5-ft. bearings, was to its deflection when the supports were 3 ft. apart, as 64 to 24, the flexibility of this rail was threefold that of a 75 lb. rail on 3-ft. bearings. Here was, therefore, a permanent way abnormally weak and flexible, its strength being only equal to that of a 57¼ lb. rail on 3-ft. bearings, and its flexibility at least four times greater than that of a 75 lb. rail on 3-ft. bearings. When he last obtained particulars of this permanent way, these rails had been laid down for eighteen years, and were still in perfect order. He believed that more was lost than gained by increasing the weight of even a double-headed rail above 70 lbs. per yard, which appeared to him to be equal to the heaviest traffic; and with cross-sleepers equidistant from centre to centre, and with a section of equal weight per yard, a Vignoles road was stronger and stiffer than a chair road; for the bearing of the rail on a chair was only 3 in., which reduced the clear bearing only from 36 in. to 33 in., the square of which was 1,089; but the bearing of the Vignoles rail on machine-planed beds was from 9 in. to 10 in. according to the width of the rectangular sleepers used, which reduced the clear bearing to 27 in. or 26 in., the squares of which were respectively 729 and 676; and the strength being inversely as the square with the sleepers 3 ft. apart from centre to centre, it followed that the strength as a girder of a Vignoles rail would be to that of a double-headed rail of equal weight in a chair road (the sleepers being the same distance apart from centre to centre), in the ratio of 1,089 to 729, or of 1,089 to 676, or nearly as 3 to 2. He therefore considered that the weight of a Vignoles rail should never exceed 70 lbs. per yard, nor be less than 65 lbs.; the minimum would be 62 lbs., if dog fastenings were substituted for through fang-bolt fastenings; but such a substitution was, in his opinion, much to be deprecated.

The section of a rail admitted of three primary subdivisions—the head, the vertical web, and the foot. The same division applied to the double-headed section, merely substituting a second head for the foot. Thus, the principles on which the rail section, shown in Fig. 2, p. 47, as outlined, applied equally to the Vignoles and the double-headed sections.

The width of the head ranged in practice from 2½ to 2¾ in. The former was till lately the rule in England; but the flat-footed rails, which had almost superseded every other form of section on the Continent and in America, and which were rapidly gaining ground in England, were usually only 2¼ in. in width of head. In Mr. Brunel's latest specification for a 75-lb. double-headed rail for the Eastern Bengal Railway, the width was only 2.3 in.; on the Grand Russian Railway it was 2.3 in.; on the Cape Railway and Swedish Government lines, the same; and the rail of the Kustendjie Railway, of the Royal Swedish, and many others, only 2.25 in. He considered 2.25 in. the proper width for lines with light and medium traffic, and 2.3 in. the maximum for lines with the heaviest traffic. In fact, it could be demonstrated that nothing was gained by increasing the width above 2.3 in. If, indeed, the wheel-treads of the rails were horizontal planes, and the peripheries of the wheels truly cylindrical, so that the contact or bearing of the wheel with and on the rail were conterminous with the width of the latter, there would be a manifest advantage in making such bearing surface as wide as possible. But in practice, the contact of the wheel and rail at any one moment was merely that of a cone laid transversely on a cylinder, and such contact, instead of extending the whole width of the rail, would, were the materials unyielding and

non-elastic, be a mathematical point without length or breadth; and, after allowing for elasticity, the actual contact at any one moment had been stated by Mr. Brunel never to exceed $\frac{1}{4}$ of an inch in width. He thought this an under-estimate; but, however that might be, it was obvious that the width of actual contact at any one moment could never amount to any considerable fraction of the width of the rail, and therefore that nothing could be added to the width of actual contact, that could in any way diminish the stress of the wheel on the wheel-tread, by increasing the width of the latter beyond the limits he had laid down. By so increasing the width of the rail-head, the overhang or false bearing of the shoulder of the rail over the vertical web that supported it was increased, and thereby, *pro tanto*, the cross strains to which the material of the rail was subjected. The contour of the wheel-tread was obviously the point of paramount importance. It was by the lamination at this surface that the rail perished. It was the weakest link in the chain, and one which, from the peculiar and exceptional conditions of the case, could not be strengthened adequately.

In ordinary cases of engineering, when a structure of given material was designed for the purpose of carrying a load, the amount of such load was first ascertained; secondly, the ultimate strength of the material; and finally, an ample margin was allowed for safety. For example, the ultimate strength of wrought iron being 25 tons per sq. in., the load on a wrought-iron girder bridge was not allowed to exceed 5 tons per sq. in. But it was, unfortunately, impracticable to apply this rule to the apportioning of the bearing surface of the rails to the load on the locomotive driving-wheels. The case was a wholly exceptional one in engineering; for not even the smallest margin for safety was practicable. It was impossible to avoid loading the bearing surface to an extent much greater per sq. in. than the greatest that any such material would be subjected to, if it could possibly be helped; for the point of contact of the wheels with the rail, supposing the material of both to be unyielding and non-elastic, would be not a surface at all, but merely a mathematical point, and the load on the driving-wheels of a locomotive was often 11 tons, the whole of which might at any moment be thrown by a jerk on a single rail.

The only circumstance that could save the bearing surface from destruction under such an emergency was the elasticity of the wheel and the rail, which allowed the periphery of the former to flatten at its contact with the latter, and the rail surface to lap round the contact of the wheel, so as to convert what would otherwise be a bearing point into a bearing surface; and it was desirable to encourage this action as much as possible, by giving the rail as much elasticity and as flat a bearing surface as was compatible with the observance of other essential conditions.

In the case of a railway with a central guide-rail, it was obvious that the wheels of the rolling-stock should be perfectly cylindrical, and the wheel-treads of the rails horizontal planes. In such a case the pressure of the wheel-tyre would be distributed over the entire width of the rail—a condition more favorable to the durability of both tyres and rails than when the pressure on the wheels was concentrated on a scarcely appreciable fraction of the width of the rail—as must be the case when the wheel-tread of the latter had for its contour a circular arc. It should be attempted in ordinary practice to approach these conditions as nearly as the coning of the wheels, coupled with the clearance or play of $\frac{3}{4}$ths of an inch allowed between the flanges and the inner surface of the rails, and also the allowance for the inaccuracy in the gauge and in the angle of the wheel-cant, due to imperfections in the laying and working of a chair rod, would permit, by making the radius with which the profile of the wheel-tread was struck as large, and consequently the arc as nearly approximate to a plane surface, as the conditions of the case allowed.

As the wheels were coned to an inclination corresponding to the cant of the rails, such coning would perfectly accord with a flat-headed rail, provided the relative position of the wheel and the rail were always kept the same by a central guide-rail; but the play allowed between the flanges and the rails, coupled with this coning, to a small extent, and the inaccuracy of gauge and cant incidental to the laying of a chair road, in a far greater measure, caused an appreciable amount of angular divergence between the profile of a perfectly flat wheel-tread and the rectilinear profile of the wheel-tyres. Sometimes the latter would bear on the inner edge and sometimes on the outer

edge of the former. It was to obviate this that the wheel-treads had been given a rounded contour. The principle was correct; but the amount of such rounding could be demonstrated to be almost inappreciable, and was generally injuriously overdone. The proper amount of rounding to be given to the upper surface of the rail—viz., the radius with which the circular arc forming the profile of the wheel-tread should be struck—admitted of accurate determination. The angle of the arc should be twice that of the maximum angle of divergence between the profile of the cone and the wheel-tread, supposing the latter to be flat.

The amount of the portion of this angle of divergence which was due to the coning of the wheels, and the clearance or play allowed between the wheel flanges and the inner surfaces of the rails, might be thus determined. As the amount of such clearance only allowed the wheels to deviate $\frac{1}{2}$ in. on each side of their centrical position, and as the inclination of the side of the cone of the wheel line was only $\frac{1}{20}$th, the utmost limits of such deviation could only raise one end of the axis $\frac{1}{40}$th of an inch and depress the opposite end to the same extent; and, taking the length of the axis in round numbers as 60 in., this would only be equivalent to an inclination of $\frac{1}{2400}$th of an inch in 60 in., *i. e.*, of 1 in 1,200, and the angle of deviation of the profile of the wheel from that of the rail-head due to this cause would be, of course, the same—that was 1 in 1,200, equal to an angle of 1 min. 51 sec. To this had to be added the angular variation in the cant and gauge of the rail due to the inaccuracies incidental to the laying and wearing of a chair road. The bed of the chair on the sleeper was 10 in., and the bed was cut to a template; and if the limit of inaccuracy in the cutting and wearing of the bed were assumed to be about $\frac{1}{4}$ in. at one end or the other, this would be equivalent to a variation of $\frac{1}{40}$, or equal to an angle of 1 deg. 51 min. 1 sec., and this, added to the angle of variation due to the coning of the wheel and clearance, would make the total angle of divergence A B C and A′ B′ C′ on Fig 1. equal to 1 deg. 27 min. 51 sec.

In this Fig., B′B represented the bearing surface of a rail, say 2 in. wide, and A B and A′ B′ the extreme positions of the wheel tyre on such a rail, supposing it flat topped; these positions being inclined to the rail surface at an angle of 1 deg. 27 min. 51 sec. To determine the radius with which the profile of the bearing surface of the rail must be described, so as to prevent the weight being ever thrown exclusively on either edge of the rail, and so that each portion of the surface might take its turn equally with the other in bearing the

FIG. 1.

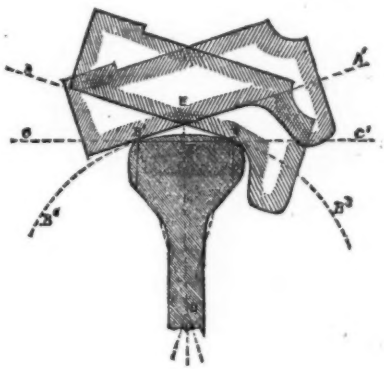


Diagram demonstrating that when B′ B = 1½ in., and the head of the rail is, therefore, 2¼ in. wide, a radius of 40 in. will give ample curvature for the wheel-tread.

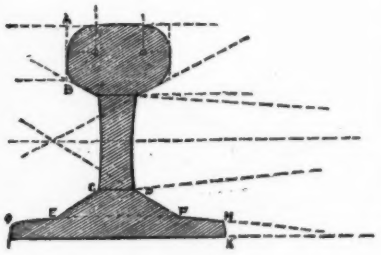
The angles D B′ B and D B B′ are each equal to 88 deg. 32 min. 9 sec. The angles C B A and C′ B′ A′ are thus each equal to 1 deg. 27 min. 51 sec., and B′ D B measures 2 deg. 55 min. 42 sec.

weight, draw through B and B′ the extreme points of contact of the wheels and rail surfaces, the lines B D and B′ D in a direction perpendicular to the lines A B and A′ B′, then the point of intersection of B D and B′D would be the centre from which the circular arc forming the profile of the wheel-tread should be struck; for it was clear that the profile of the wheel contour would be tangential to this arc in every possible position of the wheels.

The angles E B′ D and E B D being obviously similar angles, therefore B′ D B was equal to twice the angle A B C, or 2 deg. 55 min. 42 sec., and, as the side B′ B of the triangle B′ D B was equal to 2 in., and the opposite angle was equal to 2 deg. 55 min. 42 sec., the length of the sides B D and D B was 54 in., which was, therefore, the radius with which the arc forming the profile of the wheel-tread should be struck. If B′ B was equal to only 1½ in., this radius would be equal to 40.75 in. This al-

lowed for the inaccuracy of laying and wearing incidental to a chair road, but with a Vignoles rail a much flatter one would suffice. He was, therefore, warranted in adopting 40 in. as the proper radius of the profile of the wheel-tread in all cases.

FIG. 2.



Construction of Rail Section. Half full size.
The wheel-tread has a radius of 40 in.
The vertical web is profiled with a radius of 12 in.
The upper and lower fish planes are at an angle of 60 deg. to each other.

The radius with which the shoulders of the wheel-tread were rounded off was at first only $\frac{1}{4}$ in.; this was found insufficient, and the present practice ranged from a radius of .45 in. to .7 in. On the Grand Russian, and in the section adopted by Mr. Samuel, the radius was only .45 in. In the rail chosen by Mr. Fowler for the Great Southern and Western Railway of Ireland, and also in the Royal Swedish, the radius was .5 in.; in the Great Northern of France, .55 in.; and in the Eastern Bengal Railway, .6 in.

The radius of the shoulder should not be less than .5 in. nor more than .6 in.; and, in his opinion, the former dimension answered all necessary conditions, and anything more than that was injurious, as detracting from the width of the wheel-tread.

The flank of the shoulder should be vertical, as the proper function of the metal disposed in this portion of the section was literally to keep the shoulder up to the wheel, and it was obvious that the best disposition of material for this object was to carry down the flanks of the shoulder vertically till they met the upper fishing planes. This disposition of material had also the advantage of providing a better bearing for the fish-plates.

At its lower termination the vertical plane of each shoulder-flank was met by the surface intended to receive the upper bearings of the fish-plate.

It was indispensable that the upper and lower bearing surfaces of the fish-plate and rail should fulfil two conditions: first, that they should be plane surfaces; and, secondly, that they should be equally inclined to the axis of the fish-bolt, which should be placed centrically between the upper and the lower bearing surfaces.

The necessity of the fulfilment of these conditions appeared to be obvious. If the surfaces were curvilinear, the principle of the wedge was excluded, and the slightest inaccuracy in the manufacture would prevent the fish from obtaining a fair and continuous bearing on the rail. It was equally obvious that the bolt which pressed these fish-plates into apposition must be centrical, otherwise the pressure upon the upper and the lower bearing surfaces would be unequal, and the fish to that extent defective. The same objection applied to inclining the upper and the lower bearing surfaces of the fish at a different angle; the pressure on the upper and the lower bearing of the fish would in that case manifestly differ in the same ratio as the sines of the angles of their upper and lower bearing surfaces, and the effect would be the same as if, the angles being equal, the distance between the upper fishing-plane and the centre of the fish-bolt, and that between such centre and the lower fish-plane, differed in the same ratio.

The functions which the vertical web had to fulfil were simply to maintain the head and the foot of the rail in the same relative position with itself and each other, under any lateral or vertical strains to which they might be subjected in the working of the line. In modern practice the centre thickness of this vertical web ranged from .55 in., which was little more than the minimum to which it could be rolled without unduly increasing the cost of manufacture, to .7 in. A favorite dimension for the centre thickness of a rib that increased in thickness towards its junctions with the head and foot of the rail was .6 in.; but .65 in., or .7 in. were common dimensions when the section of the vertical web was parallel throughout from head to foot. He had adopted in these Tables (pp. 180, 181) in every case a top and bottom thickness of .7 in., and a thickness at the centre of .6 in., the profiles of the sides of the vertical web being circular, and drawn through these three points, *i. e.*, with

a chord equal to the depth of the web, and a versed sine equal to .05 in., *i. e.*, half the difference between the top and bottom width .7 in, and the centre width .6 in.

Horizontal lines drawn through the intersection of these arcs, with the prolongation of the fishing-planes, formed the demarcation between the head and vertical web and the vertical web and foot; therefore any one of the 41 vertical webs in the series given in the Tables (pp. 180, 181) might be joined to any of the 30 heads or to any one of the 26 feet, and thus about 32,000 varieties of rail section might be formed from such combinations. The re-entering angle between these arcs and planes was filled in by an arc of .3 in. radius.

The fixing of the angle, at which the fish-planes converged at 60 deg., was the result of a compromise. Manufacturers preferred a larger angle, so as to give the head the pear-shaped section of the Erie rail; but this increased the foot of the rail, and rendered it difficult to form a good fish, whereas with an angle of 60 deg. as strong a fish might be formed as had ever been made. The only effect on the fish of diminishing the angle from 60 deg. to 50 deg. was that in the latter case an equally strong fish might be obtained with less scantling in the fish-plates and fish-bolts. But no such increase of scantlings would be necessary with the insistent fish.

The usual depth of the double-headed rail was 5 in., but, as already shown, the strength of a Vignoles rail, laid on sleepers 3 ft. apart from centre to centre, exceeded that of a double-headed rail of equal section and depth laid on sleepers the same distance apart, nearly in the ratio of 3 to 2; and, therefore, to insure the same strength and stiffness, the depth of the Vignoles rail might be, as compared with that of the double-headed rail, in the ratio of 2 to 3. In practice the depth had hitherto been in excess of this, for convenience in fishing only. The Royal Swedish rail and the Grand Russian rail had each a depth of $4\frac{5}{8}$ in.; the Morayshire, the Kustendjie, the Great Southern and Western of Ireland, and the Swedish Government rails, had each a depth of $4\frac{1}{2}$ in., while the rails for the Cape were $4\frac{1}{2}$ in. deep, and his own $65\frac{1}{2}$ lb. section, laid on the West Cork, the Cork and Kinsale, the Cork and Macroom, and the Cork and Limerick Direct Railways, had a depth of 4.3 in., though for heavy traffic he made the depth 4.55 in.

He now came to the foot of the rail. The dimensions of the trapezium, C D F E (Fig. 2. p. 178), which formed the upper portion of the foot, and the sides of which, F D and C E, constituted the lower fish planes, should be the same for all weights of rail. Its top width, C D, was .7 in., its bottom width 2.1 in., and its depth .45 in. From C and D the profiles of the upper surface of the foot extended at an inclination downwards of 1 in 10, till they attained the full width intended to be given to the foot, and from these terminations vertical lines—G I H K—were dropped .375 in. in depth, for the thickness of the toe, which was fixed by manufacturing considerations, and was the same in all cases, and a horizontal line drawn through I to K completed the profile of the foot.

The width of the foot should be at least sufficient to admit of through fastening, consisting of bolts passing through the sleepers, fixing into fang-nuts abutting on its lower surface. He thought the practice of nailing the rail to the sleeper by exaggerated brads, called dog-bolts, could not be too strongly deprecated. He had found a width of $4\frac{1}{2}$ in. sufficient for fulfilling these conditions; and for the heaviest traffic, it appeared to him that a width of 5 in. was ample. If this width were exceeded, the difficulty of rolling, and consequently the cost of the rail, would be greatly increased.

He was aware that there were advocates for making the foot, or lower flange, very wide in proportion to the depth of the rail, in order to obtain a greater amount of lateral resistance; but regarding a problem of this sort, it might be said *solvitur ambulando*. The Vignoles section had long been in general use, both in Europe and America, and on both continents, after experience gained over a period of ten or fifteen years' working, and on a length of over 10,000 miles of railway, a width of 4 in. had been found sufficient, and was still adhered to. And if a base of 4 in. was thus sufficient with only dog-bolt fastenings, *a fortiori*, must a width of $4\frac{1}{2}$ in. be ample with such superior attachment to the sleepers as was effected by through fastenings, such as fang-bolts.

He exhibited a diagram containing sections of 30 heads of rails, varying in top width from 2.25 in. to 2.5 in., the bottom width of all being .7 in., and in depth of shoulder from .9 in. to 1.0 in., the total

depth ranging from 1.34 in. to 1.521 in., and the weight increasing from 25.76 lbs. to 32.39 lbs. per yard. On the same diagram were also shown 41 vertical webs, varying in depth from 1.9 in. to 2.9 in., the width at the top and bottom being 7 in., and the thickness at the centre .6 in., the weight varying from 12.2 lbs. to 18.20 lbs. per yard. There were also shown 26 sections of feet, varying in depth from .898 in. to 1.023 in., and in width from 4 in. to 6½ in., and in weight from 24.06 lbs. to 39.43 lbs. per yard. Every one of these heads would fit on to every one of the vertical webs; the number of combinations of the 30 heads and the 41 vertical webs was therefore equal to 30×41, or 1,230; and every one of these 1,230 combinations of heads and vertical webs would fit on every one of the 26 sections of feet, making the total number of combinations 31,980; the rails so compounded varying in width of foot from 4 in. to 6½ in.; in depth from 4.1 in. to 5.4 in., and weighing from 62 lbs. per yard to 90 lbs. per yard. The last weight was due to the combination of the heaviest head, the highest vertical web, and the widest foot.

He did not advocate all these combinations or any extreme weight. He only mentioned the number of possible combinations to show that the Tables covered the widest conceivable range of practice. Neither did he advocate, for light or medium traffic, a greater width of head than 2¼ in., a greater width of foot than

Heads varying in width from 2.25 in. to 2.5 in., and in depth from 1 340 in. to 1.521 in., and in weight from 25.76 lbs. to 32.39 lbs.

Number.	Width in Inches.	Depth in Inches.	Depth to Bottom of Shoulder.	Weight in Lbs.
1	2 25	1.340	– .9	25 76
2	"	1.374	– .925	26.32
3	"	1.396	– .95	26.68
4	"	1.421	– 975	27.44
5	"	1.446	1.0	28.01
6	2 30	1.361	– 9	26 55
7	"	1.366	– .925	27.12
8	"	1 411	– .95	27.70
9	"	1.436	– .975	28.27
10	"	1.461	1 0	28.85
11	2.35	1.376	– .9	27.33
12	"	1.401	– .925	27.92
13	"	1 426	– 95	28.51
14	"	1.451	– 975	29.10
15	"	1.476	1.0	29 69
16	2.40	1 391	– .9	28.40
17	"	1.416	– .925	29.00
18	"	1.441	– .95	29.60
19	"	1.466	– .975	30.20
20	"	1.491	1.0	30 80
21	2.45	1.406	– 9	29.20
22	"	1.431	– 925	29 81
23	"	1 456	– .95	30.42
24	"	1.481	– .975	31.03
25	"	1.506	1 0	31.65
26	2.50	1 421	– .9	29.89
27	"	1 446	– 925	30 52
28	"	1.471	– .95	31 14
29	"	1.496	– .975	31.77
30	"	1.521	1.0	32.39

CONSTANTS.

In all cases, the width of the top of the foot, of the bottom of the head, and of the top and bottom of the vertical web, was .7 in., and the profile of the latter was struck with a radius of 12 in. The fishing planes were inclined to the transverse axis of the rail section at an angle of 30°; the thickness of the metal at the toe of the foot was .375 in. from which its upper surface rose at an inclination of 1 in 10. The radius of the wheel-tread was always 40 in., and that of the shoulder .5 in.

Vertical Webs varying in depth from 1 9 in. to 2.9 in., and in weight from 12.2 lbs. to 18.2 lbs.

Number.	Depth in Inches.	Weight in Lbs.
1	1.9	12.2
2	1.925	12 35
3	1 95	12 5
4	1.975	12.65
5	2.0	12.8
6	2.025	12 95
7	2 05	13 1
8	2.075	13.25
9	2.1	13.4
10	2 125	13 55
11	2 15	13 7
12	2 175	13.85
13	2.2	14 0
14	2.225	14 15
15	2 25	14.3
16	2 275	14 45
17	2.3	14.6
18	2 325	14.75
19	2.35	14 9
20	2 375	15.05
21	2 4	15 20
22	2.425	15.35
23	2.45	15.5
24	2 475	15.65
25	2.5	15.8
26	2 525	15.95
27	2.55	16.1
28	2 575	16.25
29	2 6	16.4
30	2.625	16 55
31	2.65	16.7
32	2.675	16.88
33	2 7	17.0
34	2.725	17.15
35	2.75	17.3
36	2.775	17.45
37	2.8	17 6
38	2.825	17.75
39	2 85	17.9
40	2 875	18.05
41	2.9	18 20

Bottom Fanges or Feet, varying in breadth from 4.0 *in. to* 6.5 *in., and in depth from* .898 *in. to* 1.023 *in., and in weight from* 24.06 *lbs. to* 39.43 *lbs.*

No.	Breadth in Inches.	Depth in Inches.	Weight in Lbs.
1	4.0	—.898	24 06
2	4.1	— 803	24.64
3	4 2	—.908	25 22
4	4.3	—.913	25.81
5	4.4	— 918	26 40
6	4 5	—.923	27.00
7	4 6	—.928	27.60
8	4 7	— 933	28.21
9	4.8	—.938	28 82
10	4.9	—.943	29.44
11	5 0	—.948	30.06
12	5 1	— 953	30.69
13	5.2	—.958	31.32
14	5 3	—.963	31.95
15	5.4	— 968	32 58
16	5.5	—.973	33.22
17	5.6	—.978	33.86
18	5.7	—.983	34 51
19	5.8	—.988	35.16
20	5.9	—.993	35.81
21	6 0	—.998	36.47
22	6.1	1.103	37.13
23	6.2	1.008	37.80
24	6.3	1.013	38 47
25	6.4	1.018	39 15
26	6.5	1.023	39.43

4½ in., a greater depth than 4.3 in., or a greater weight per yard than 65½ lbs.; or for the heaviest traffic, a greater weight than 70 lbs. per yard, a greater width of head than 2.3 in., a greater depth than 4.55 in., or a greater width of foot than 5 in.

As regarded fastenings, the only description of joint now employed was the fish-joint; and of this there were two varieties —the suspended and the insistent fish. The former had to perform two functions, the latter only one. The suspended fish had first to act as a girder, by giving vertical strength to the joint between the two rails; the fishes required, therefore, to be as long and deep as possible, to be fastened by four bolts, and to have the bearing edges as nearly horizontal as the fulfilment of other essential conditions permitted, in order to keep the ends of the two rails in accurate apposition, so that the joints might offer no obstacle to the smooth moving of the wheels.

The insistent fish was not required to add to the vertical strength of the joint, such joint being supported by the joint sleepers; the only function it had to fulfil was to maintain the extremities of the conterminous rails in accurate apposition. For this purpose a much shorter and shallower fish than would be required in suspension answered every purpose, and there might be only three bolts instead of four, as the centre bolt, acting immediately at the junction of the rails, had then a greater power of holding them in accurate apposition than it could exert in any other position. Moreover, there was no occasion to sacrifice the section of the rails to the perfection of carrying out the principle of fishing, as the angle of the bearing surface of the fish was comparatively immaterial. The suspended fish was manifestly defective as a mechanical arrangement, when compared with the supported fish, as the object to be kept in view was to approximate as closely as possible to the conditions of a bar of uniform strength. Now it was obvious that a suspended fish-joint could never offer nearly the same resistance to the load as an unjointed rail of the same bearing length; it therefore became necessary greatly to diminish the length of the bearing whenever a suspended joint occurred, and this inequality of bearing length was continued throughout the length of the rail, the bearing gradually diminishing to the joint; and as the resistance was as the square of the bearing, this inequality was manifestly incompatible with any near approximation to the conditions of a bar of uniform strength.

He submitted diagrams showing the best arrangements for the fished joints and fastenings for the Vignoles rail. It would be seen that the fish was an insistent fish, and that it was a double fish, horizontal as well as vertical; for the wide horizontal under surface of the rail foot was kept in close juxtaposition with the wrought-iron bed-plate which received the ends of the rails, extending the full width of the rectangular joint-sleeper, a width of 10 in. on lines of light traffic, which, if thought desirable, might be increased to 12 in. on lines of the heaviest traffic. And the ends of these rails were fished to this bed-plate by two horizontal fish-plates with three through fastenings to each centre-bolt, being placed at the most effective point, viz., the junction of the rails.

These bolts, three on each side, passed through the sleepers, and were screwed underneath it to a bar $\frac{5}{8}$ in. by $2\frac{3}{4}$ in., acting as a common nut to the three bolts, thus making the rails practically a continuous bar of uniform resistance, and the sleeper one mass, so to speak, with the rails. Joints of

this kind were quite imperceptible when running over the line, and the rails approximated far more nearly to the conditions of a continuous bar of uniform resistance than in the case of a suspended fish.

There might be an advantage in using Parsons' patent bolts for the fish and fang bolts. He had never tried them himself; but their principle was that of equalizing, by fluting the section and strength of the shank to that of the screw-tapped extremity of the bolt, so as to obtain uniform strength and elasticity; this was undoubtedly an improvement.

He always specified for fish-bolts with their inner surface concave, and the corner well preserved instead of being rounded off; by this means the bearing took its grip at the greatest possible distance from the centre of the bolt, and greater leverage was thus obtained to counteract the tendency of the nut to untwist. He had never known such nuts to work loose.

One of the greatest advantages possessed by the Vignoles road, where the rails were fixed directly to the sleepers on machine-planed beds, by means of through screw fastenings, was the absolute uniformity of gauge and cant of rails which was thereby insured, and which rendered practicable a much flatter wheel-tread, and a much narrower clearance than could be attained on a chair line; and these advantages greatly conduced to smooth running, and the preservation of rail surface and rolling stock.

The introduction of the Vignoles rail in this country had been greatly retarded by the defective manner in which it was at first, and was still sometimes, laid down, viz., on half-round sleepers, and merely secured by spikes, sometimes without even a nick at the end of the rails to prevent them from travelling. No line of Vignoles rails should be passed unless the sleepers were rectangular; for the bearing of their section on the sleeper should be at least equal to that of a chair on its sleeper, and that amounted to 40 sq. in. This was somewhat exceeded on a rectangular sleeper of 9 in. wide, which, with a width of 4.5 in. for the rail foot, gave a bearing of 45 in. for each point of support; but when a Vignoles rail was laid on a half-round sleeper, scarcely one-half of the requisite bearing could be obtained, and that only on sap-wood. Another advantage of this system was that with 3-ft. bearings, the clear bearing between the supports was diminished, as compared with a double-headed rail, from 33 in. to 26 in., and the stiffness of the rail thereby increased inversely as the squares, or in the ratio of nearly 3 to 2.

He saw no reason why a steel-headed rail, of the Vignoles section, dovetailed in the manner described by Mr. Menelaus, should not last as long as one entirely of steel at double the cost.

He thought it would be admitted that puddled bars made the most enduring rails; but it was impossible to force iron of this description, with rollers such as were usually employed, into the slender toes of a wide-footed rail. He would submit that this difficulty might be overcome by employing a third roller set transversely to the other two, for rolling the under surface of the foot, an expedient very generally adopted on the Continent in rolling wrought-iron girders of similar section.

Mr. G. B. Bruce said, with regard to the specifications for rails, he was not prepared to throw the blame upon or to give the credit to Boards of Directors, or foreign governments, but was rather disposed to take the responsibility upon himself in cases in which he was concerned. So far from the iron-masters having any reason to complain of the specifications of engineers, he thought that they had learned a good deal from those specifications. The mode of manufacture which Mr. Williams had so graphically described and so strongly recommended was precisely the same which many engineers had long given in their specifications, and which the great bulk of iron-masters had been driven to adopt, by the engineers so requiring the puddle ball to be hammered in the way described. No doubt, the great secret of a good rail was that it should be homogeneous; but that was not the sole condition, otherwise it would only be necessary to fall back upon the old cast-iron rail, which was homogeneous but brittle.

He was ready to admit that in the matter of rails, as well as in many other things, tests were often carried to an injurious extent; but when judiciously applied, they were very valuable. When specifications provided that a rail should not break under a certain falling weight, and yet not bend more than a given quantity,—these conditions secured the possession of the two requisites, hardness and tenacity, so necessary for a good wearing and safe rail.

He was disposed to think that steel rails

were not altogether perfect. Out of one lot of 200 tons which he had used recently, five of the rails broke, literally on being thrown out of the wagon; and in the present process of manufacture, individual steel rails were as likely to be defective as iron rails, and could not be implicitly trusted. He had tested some flat-bottomed steel rails, punched in the lower flange, and had observed that when the holes were not near the part on which the weight of 16½ cwt. fell, the rail did not break, though the fall was 20 ft. But if the same rail was so placed that the holes were in the middle between the points of support, the rail broke at a blow with a 5 ft. fall. The holes ought to be drilled and not punched in every case when dealing with steel rails.

Mr. R. P. Brereton dissented altogether from the view that good iron rails could not be made if pains were taken; or that it had become indispensable to seek for other materials, such as steel, except for special occasions. There was as yet no sufficient experience of the effect of hard steel rails upon the tyres and rolling stock, by far the most expensive part of the property belonging to Railway Companies. With regard to the deterioration in the manufacture of rails, when these had to be turned out quickly and in large quantities it was not to be expected that they should at the same time be made good. There was no desire to produce a lasting article; and when Railway Companies undertook to make their own rails, they did not make them better than the iron-masters. He had taken the pains to ascertain what had become of about 24,000 tons of rails made in Wales in 1849 for the South Wales Railway, on which there was a large mineral traffic. It was 100 miles in length and was opened in 1850. In the first nine years, out of the 24,000 tons there were only about 1,080 tons lost, or 4½ per cent. of the original quantity; and of the remainder there were at the present time 12,000 tons in use, and wearing out at the rate of about 5 per cent. per annum of the original quantity. This was principally at stations and inclines; and switches and crossings of the same iron were still in use. The life of these rails had already averaged fifteen years, and at the rate now wearing out would ultimately average seventeen. If iron-masters could make such rails years ago they could make them now; but an inducement was required which was not offered.

M. T. E. M. Marsh stated that the rails alluded to by Mr. Brereton were made from cold-blast iron, and a great part of it was worked into refined metal. The manufacture was well cared for. Such good rails were not now generally made. A great demand for common rails had been met by cheaper and inferior material and processes. The price had been fixed upon a sliding-scale based on the price of common bar-iron, which was somewhat lower than the price of rails, the price of the latter being then about 20 per cent. or 25 per cent. higher than that of bar iron at certain works, because it was supposed that rails were more expensive to produce. To this was added from 15s. to 25s. per ton extra. Thus assuming bars to have been at £6 per ton, the cost of the rails would have been from £8 to £9 per ton. The rail was made from puddled bars, one of the principal advantages of that process being that the result of the yield of the puddlers might be tested every day, and at any moment. In that way a good welding quality, and a strong, solid rail, could be obtained. The rails referred to were not "cold short." Puddle balls might be badly made, and in fact frequently did inclose chilled cinder and other impurities, which would cause the iron to be crushed off the rail in large pieces.

In some districts it would probably be found better to use puddle balls direct, and not puddle bars; but the quality of the materials, processes, and appliances of the manufactures must be judged of by the engineer.

Mr. Marsh then referred to some samples of rails he had placed on the table:

No. 1. Rail and piece of slab, made for Mr. Brunel by Messrs. Thorneycroft, in the year 1858; also small experimental lots, made in the year 1848; the top slab being formed out of a single bloom of charcoal iron. The rails were laid on the Great Western Railway, and were doing good service now, where from three hundred to four hundred engines were passing over them daily.

No. 2. Similar to No. 1, made by Mr. A. Hill. The top slab consisted of Bowling iron; used in the year 1858 and subsequently, on lines in charge of Mr. Brunel, for points and crossings, with very good results.

Nos. 3, 4, and 11. Specimens of puddled

steel rail, made for railways in charge of Mr. Brunel, illustrating apparently good fracture and uncertain welds; and samples of steel tops separated by wear. These rails were generally unsatisfactory.

Nos. 5 to 9. Specimens of rails made between the years 1846 and 1850 and subsequently, for Mr. Brunel, being of the class referred to by Mr. Brereton, as having been laid on the South Wales division of the Great Western Railway, between Grange Court and Swansea, a distance of 95 miles, where they were subject to the excessively heavy wear of the inclines in the Neath and Swansea district.

The duration of the bridge rails, of which 24,000 tons were laid, was shown in the following statement:

			Worn out. Tons.
From opening of line in 1850 to June 30, 1859		.	1 081
" June	1859 to July 1863	. . .	4,598
" July	1863 to February 1864	. . .	763
" February	1864 to July 1864	. . .	494
" July	1864 to December 1864	. . .	784
" December	1864 to July 1865	. . .	942
" July	1865 to Decen ber 1865	. . .	820
" December	1865 to July 1866	. . .	888
" July	1866 to December 1866	. . .	658
" December	1866 to July 1867	. . .	563
" July	1867 to December 1867	. . .	557
			12,148

The same quality was also laid on the Great Western Railway, the Wilts and Somerset, exclusive of the Bath branch, the Berks and Hants, on part of the Oxford and Birmingham, and on heavily worked parts of the South Devon Railway, and generally, with few exceptions, on other lines forming part of the Great Western system.

The merits of the various qualities, and the best mode of obtaining good rails, were continuously and rigorously tested by Mr. Brunel, and the best results were invariably obtained from the iron-master, who did not object to, but invited and approved rigid inspection, and desired to have the benefit of Mr. Brunel's valuable experience, and to satisfy him that all details were carried out to insure good results.

In June, 1853, Mr. Brunel addressed a letter to twelve of the principal iron-masters in these terms:

"You are probably aware that it is a very general complaint amongst engineers and railway companies that they cannot now obtain with any certainty rails of a good quality.

"There is every reason to believe that a little more care and skill in the selection of the quality of metal, at all events for a portion of the pile forming the rail; and somewhat more care bestowed in the manufacture, would secure a very superior rail to those now generally manufactured, without any very great increase of expense. I am desirous of obtaining, to lay before the Directors of the Great Western Railway Company, proposals for the manufacture and supply of about 4,000 tons of such superior quality to be used as an experiment upon a line of railway where there will be considerable traffic.

"I enclose a specification of the rail required; but I should prefer leaving the choice of means to those whose practical knowledge must be much greater than mine, and I should feel satisfied if I am assured by a respectable manufacturer that he will undertake to use his best endeavors to meet the objections raised, and to make a really good rail. I assume, although this is a time at which you are all very independent of orders, yet that you would be glad to make the attempt to regain the character which I assure you English rails are fast losing, and if you are disposed to make a trial with 1,000 or 2,000 tons, and will state the mode of manufacture you would propose, and the price, I shall feel obliged. The delivery should be immediate, or at all events early."

Extract from Specification, referred to in Mr. Brunel's letter, for Bridge Rails for Great Western Railway, June, 1853.

"One-third in quantity of the whole pile from which the rail is to be rolled is to consist of a slab of a single piece, forming the whole top of the pile, and so placed as to form the upper portion of the rail when finished. This slab shall be made of No. 2 iron, hammered, or of such other defined quality as may be mentioned in the tender and agreed upon.

"The rest of the pile shall be formed of whole lengths of bars, and no rail-ends, or awkward-shaped pieces of scrap shall be used."

Mr. J. Strapp had not much experience of the relative values of steel and iron rails on the South Western Railway. Some steel rails had been laid down four years, and during that time about 10,000,000 tons had passed over them without their showing any perceptible signs of wear. At the same time iron rails had been down in the same district eight years, and probably

from 19,000,000 tons to 20,000,000 tons had passed over them. He was not prepared to say that iron rails should be replaced by steel rails where they lasted so long. On the contrary, he thought that where iron rails would last over six years, steel rails, at their present price, could not be substituted with economy. He produced two specimens of rails, one of which had been down twenty-five years, on the Gosport branch, about half a mile from a station, over which not more than 4,000,000 tons had passed; the other had been down eight years in Battersea Fields, and over this 17,000,000 tons had passed; the average speed of the trains, in both cases, being about thirty miles per hour. In calculating these weights he had, of course, taken one-half the gross weight of the trains passing over the one line as that due to duty performed by one rail. Time, therefore, was not always a guide to the true worth of rails.

Mr. Peter Ashcroft produced some specimens of rails which had been used on the South Eastern Railway. Some of them had been down twenty-four years. One, an old Dover rail, put down by Sir William Cubitt, had been passed over by one hundred and five thousand trains, as nearly as could be estimated, equal to 13,000,000 tons. This was on the down line, near the Dover Station, so that every train had to pass over it. Another, of which the maker was unknown, was from the Rochester and Gravesend line, and had been down since the year 1845. It was only a 66 lbs. rail, and the quality was excellent; there was a large quantity of similar rails still down on that line. Another specimen which had been down since 1865 on the Charing Cross line between Cannon street and London Bridge, was known to have had a hundred and seventy thousand trains passed over it, amounting to 21,000,000 tons. Only one side of the rail had as yet been used during the two years and eight months which had elapsed since it had been laid down.

He thought the South Eastern Railway Company had benefited very much by leaving, to a great extent, the specification and manufacture of the rails to the manufacturers, subject to a satisfactory guarantee.*

Mr. Marsh inquired whether the guarantee had worked satisfactorily. It was a question of what rails had gone back to the manufacturer.

Mr. Ashcroft replied that one manufacturer had supplied 25,000 tons of rails, and the failures had not been more than 1 per cent. On the Charing Cross line, where the traffic was very heavy, 193 trains a day passing over one line of rails, the failures were as much as 10 per cent. Care was always taken to obtain a sufficient bond of indemnity for a term of not less than seven years; and for five years on the Charing Cross line.

Mr. W. Mills said that a large number of steel rails had been laid on the London, Chatham and Dover Railway. On a length of six miles, originally laid with iron, but which had been relaid with steel rails, he had reckoned the number of trains which passed over three different parts, and had found that in one case, 8,500,000 tons had been carried, in another case 8,750,000, and in a third 9,375,000 tons; the rails showed no appreciable sign of wear. Some steel rails, for stock rails for switches, had been laid down at Stewart's Lane, where formerly new iron rails were laid on an average every three-and-a-half months. Those rails had been down three years and three months, and were now in good order, and would probably last another year or more. From this latter instance it appeared that the power of resisting wear and tear in steel rails amounted to fourteen or fifteen times that of iron rails.

Mr. Joseph Taylor thought it would be a misfortune if the impression arose that the interests of manufacturers and engineers were antagonistic. Their interests must be identical; the only difference being that the engineer wanted the best rail for the least money, and the manufacturer wished to make the best rail he could and to get the best price for it.

There was room for wider difference of opinion as to the best means of obtaining the best rails, and the question seemed to be narrowed into that of specifications or no

* Extract from the South Eastern Railway Company's Specification for Rails:

"The Directors will not object to receive tenders for the 10,000, 5,000, and 1,400 tons of rails respectively, manufactured according to the iron-master's own specification, provided he can satisfy them of the sufficiency of the material to be used and the mode of manufacture, and enter into sureties for a guarantee of not less than seven years. In any case, it is to be distinctly understood that this specification is intended to convey and mean, that when any of the rails are once laid down and being run over, any perceptible lamination, crushing, splitting, or breaking taking place within the period of the seven years (not being fair wear and tear), such rail or rails shall be subject to a total rejection without being turned over, and must be cast aside and replaced by other sound rails at the contractor's cost. Those rails laid down at stations and within the distance signals are excluded from the obligations of this clause, except they are found unsoundly manufactured."

specifications. He was not prepared to say that engineers ought to throw away specifications altogether, and put themselves entirely into the hands of the iron-master; but it was possible that specifications had been pushed too far. He believed they were framed, in the first place, from the best possible information to be obtained; but he thought engineers shut themselves out from improvement and discovery in the trade, when they adhered for some years to the same specification. There had been some inconsistency in the way manufacturers had been compelled to work. It was only reasonable that, if a manufacturer was required to make a rail to produce certain results, he should be at liberty to make it according to the best of his judgment. Specifications had apparently been directed too much to the production of a high quality of bar-iron, to the neglect of the wearing quality of the metal. The heavy falling test, and the heavy suspending test, tended to produce bar-iron of high quality, but that iron was deficient in hardness and wearing quality. A little hardness might be admitted into the manufacture of rails with great advantage; and yet the rails should be sufficiently tough to resist any impact in the course of the ordinary traffic. Considering the comparative scarcity of steel-producing ore and the high price of steel rails, he thought that, for some time at least, the bulk of the supply of rails must be from iron; and so long as a thoroughly good iron rail could be made for from £6 10s. to £7 per ton, to last fourteen or sixteen years, of which there was no doubt, he did not consider that the days of the iron-master were numbered.

Mr. W. Adams stated that, in the month of October, 1862, 20 tons of Bessemer steel rails were laid down on the North London Railway, over which 254,250 trains, estimated to weigh 38,137,500 tons, had passed. He had lately measured them and found that they had worn down about $\frac{3}{16}$ of an inch. He thought that each head might wear down about $\frac{1}{4}$ of an inch, and this gave the means of estimating the durability of the rails. Between 13,000 and 14,000 rails had since been laid, and he was informed that there had not been a single failure in one of them. Some crossings leading into Dalston Junction had been laid between three years and four years, and the rails were still in good working order.

Mr. Zerah Colburn had received a letter from the general manager of the Erie Railroad, enclosing a report to the Chairman of the line, in which he stated that during the month of January upwards of one thousand rails had been broken on that line, and also that he believed the month of February would show a still worse result. Another correspondent had informed Mr. Colburn that within his knowledge, on the Hudson River Railroad, a double line, 144 miles in length, in one day, 113 rails had been found broken, during what was called a "cold snap." He had received a letter from a friend in Eastern Canada, three or four weeks ago, where possibly the temperature was lower than on the lines mentioned, and the mercury at the time the letter was written was 14 deg. Fahrenheit below zero. At Toronto there had been unusual cold, and the mercury had ranged from 13 to 17 deg. below zero. He had no reason to doubt the statements as to the breakages of the rails.

Rails in the United States were usually of the Vignoles section, and weighed 64 lbs. to 74 lbs. to the yard. The Manager of the Erie Railroad had asked his Directors to authorize him to complete the renewals for this year, to the extent of 25,000 tons, in steel, and not one steel rail had broken, although their weight was only 56 lbs. to the yard, and some steel rails had been down for the last five years. He might add that the Hudson River Railroad was then being entirely relaid with steel rails.

Mr. W. Bragge said, in reference to Mr. Colburn's statement as to the serious disaster on the Erie Railway, for such he called the great destruction of rails, the engineer had stated that the month of February would show a greater destruction of iron rails; but he went on to state that the only portion of the line on which trains could run with safety and speed was that portion laid with steel rails, and that no fault could be found with the ten miles of track laid with the Bessemer steel rails; of these only one had broken during the winter, and no lamination and very little wear was perceptible. It should be borne in mind by those who were using steel rails, that iron rail-makers had the experience of thirty or forty years; whereas steel rail-makers had been really at work only since the end of the year 1861. Upon him first devolved the duty of offering steel rails for sale; at that time the steel rail was looked upon with doubt and distrust, and only by

offering rails to make into points and crossings, on trial, to be paid for when they had earned their value, was it possible to sell them in England. He claimed for the makers of steel rails, that they had availed themselves of every branch of scientific knowledge which could be brought to bear upon their work; and he contended that the progress of seven years had not been unsatisfactory.

Mr. R. Price Williams observed that on the North London and the London, Chatham, and Dover Railways the life of iron as compared with steel rails was certainly of the briefest, while, on the other hand, the iron rails on the Southeastern Railway appeared to have shown an amount of endurance almost as remarkable as the highly phosphorized iron rail on the North-eastern Railway.

The consideration of the use of steel instead of iron rails was, after all, an engineering and economical question, which a more extended experience of the superior endurance of steel could alone determine. As far, however, as he could gather, there could be no question as to the preference of steel rails on main lines exposed to heavy traffic and high speeds, where the maximum life of iron rails did not exceed eight years.

The accuracy of the data on which the calculations of the Author's table were based had been called in question; but he had carefully gone through them with Mr. Sandberg, and had found them perfectly reliable. Objection had also been made to the extended period taken for the life of steel rails; he apprehended that the Author had only assumed such as affording the only available means of comparison with iron rails of a proportionably long life, such as might be anticipated where they were exposed to the small wearing action of light traffic. He thought, however, that twenty years' life for steel rails was quite sufficient for all purposes of comparison, as it was evident that where iron rails had a life of even fourteen years, it was cheaper, at the present prices of steel rails, to use that material.

Tabular Statement, showing how an Annuity of 10*s.* 5½*d. per Ton will Recoup the difference between Steel and Iron Rails* (£6 10*s. per ton*) *in a period of* 20 *years.*

Dr. Cash advanced at 5 per cent. interest, £6 10s.			Annuity, £0.5215795.	Cr.
	Principal recouped.	Interest.		
	£.	£.		£.
To 1 year's instalment	0 1963130	0 3252665	To 1 year's annuity	0.5215795
2 " "	.2064010	.3151785	2 " "	.5215795
3 " "	.2167295	.3048500	3 " "	.5215795
4 " "	.2275585	.2940210	4 " "	.5215795
5 " "	.2389400	.2826395	5 " "	.5215795
6 " "	.2508870	.2706925	6 " "	.5215795
7 " "	.2634255	.2581540	7 " "	.5215795
8 " "	.2766010	.2449785	8 " "	.5215795
9 " "	.2904330	.2311465	9 " "	.5215795
10 " "	.3049540	.2166255	10 " "	.5215795
11 " "	.3202030	.2013765	11 " "	.5215795
12 " "	.3362125	.1853670	12 " "	.5215795
13 " "	.3530280	.1685515	13 " "	.5215795
14 " "	.3706755	.1509040	14 " "	.5215795
15 " "	.3892135	.1323660	15 " "	.5215795
16 " "	.4086745	.1129050	16 " "	.5215795
17 " "	.4291040	.0924755	17 " "	.5215795
18 " "	.4505605	.0710190	18 " "	.5215795
19 " "	.4730830	.0484965	19 " "	.5215795
20 " "	.4967430	.0248365	20 " "	.5215795
	6.4997400	3.9318500		£10.4315900

Principal £6.4997400
Interest 3.9318500
£10.4315900

As per contra.
Annuity required for one mile single line, £62 11*s.* 9*d.* (Iron rails and steel rails, 75 lbs. per yard.)

He was unable to comprehend why Mr. Bell, at the outset of his interesting account of the iron rail manufacture in the Cleveland district, should lay so much stress upon the superior advantages afforded by the process of puddling, in getting rid of the phosphorus, when it appeared from his subsequent remarks that the presence of this substance in certain proportions was essential to the production of a sound and durable iron rail. That an excess of phosphorus did conduce to the hardness of iron rails there could be no question; but he thought most engineers who had experience of cold short iron would confirm the opinion, that such additional hardness was obtained at the greatly increased risk of sudden and perhaps disastrous breakage of iron rails.

He was disposed to think that the efforts alluded to, as being made to produce sound iron rails out of highly phosphorized Cleveland iron, would prove unsuccessful; if, however, any practicable means could be devised for getting rid of the phosphorus, and of producing good steel out of Cleveland iron, the discoverer would undoubtedly confer a great benefit, not only upon that district but upon the country generally.

He had prepared a tabular statement with the view of showing, that when compared with the present and future advantages to be derived from the substitution of steel for iron rails, the difference in first cost was not of the importance that might at first be imagined.

It would be seen that by dealing with the difference in cost between iron and steel (£6 10s. per ton), as a deferred annuity, the small annual payment of 10s. per ton, during a period of twenty years, would recoup the principal with interest at 5 per cent. during that period. He might mention that on the main line of the Great Northern, where the average life of an iron rail was only eight years, the cost of renewals of the rails alone amounted on an average to £1 per ton per annum. It was evident, therefore, that under such circumstances the adoption of this principle of deferred annuities would insure a saving of at least 50 per cent.

Mr. Bidder, Past-President, had never in the course of his practice pretended to dictate to the manufacturers how iron should be treated; but he had always endeavored to obtain the best quality. Engineers were often overruled by their masters, the Directors; and there was apparently only one species of test they were capable of appreciating, and that was the lowest price. Whether as regarded locomotives, or steamboats, or the manufacture of rails, he should consider it simple affectation to assume that he, as an Engineer, had such a knowledge of details that he could dictate the mode in which they should be constructed or produced. He knew one instance of the position he desired to lay down, where in the case of some steamships, the result was that when a sum of about £120,000 had been spent in six steamers, five had never been used at all; and the only one that was used did not make a single voyage without loss. As regarded iron rails, every manufacturer, urged by his own particular interest, directed his attention to the mode of manufacture most suitable to his own locality and the material he had to deal with. Now wherever Mr. Bidder was permitted to have his way, he specified what he wanted, the test, the power of the metal, and its other qualities; and then he said to the manufacturer that was what he required, and those were the tests which he should apply; and he then advised the acceptance of the tender after judging of the character of the men who tendered. He necessarily inferred that they were men satisfied with their own mode of manufacture, and that he might rely upon them to make the iron in the way they stated. By that means he had a much better surety than if he had tried to force upon them a mode of manufacture to which they had not been accustomed.

With regard to rails, all views as to the peculiar class of metal suitable for rails had been, from the first initiation of railways, subject to violent anomalies. He remembered a time when everybody assumed that only cast iron was fitted for rails, when all at once it turned out that wrought-iron rails were much more durable. It must be borne in mind that, on a railway, no rail could be broken by pressure. Take a bearing 3 ft. long, and an engine 30 tons in weight, rolling over it at a speed of 40 miles an hour. It was well known that in 3 ft. a rail would bend more than $\frac{1}{4}$ of an inch before it would break; but if there were no rail at all, at 40 miles an hour the wheel of an engine would not deflect the $\frac{1}{8}$th of an inch from gravity; therefore, if a rail deflected more than $\frac{1}{8}$th of an inch, no further pressure from the engine could occur. But what had to be dealt with in rails was impact and rub-

bing; the latter being the most serious question. He did not know how a test for the grinding of a locomotive wheel could be applied, unless by means of a huge grindstone; and that would not give the exact effect.

Mr. Bessemer had been a great benefactor to railways and metallurgy in general; he had given an impulse, the effect of which could hardly at present be foreseen; but he believed the result would be to produce eventually a cheap and good rail. He did not care so much about its tensile powers, but rather its capacity to sustain the grinding impact of a locomotive engine, running at the rate of 40 to 50 miles an hour.

At the present day the popular cry was to close the capital account of companies. But if it were proved beyond doubt that a rail which cost £14 per ton was the one to be adopted in lieu of the present rail at £7 per ton, who was to provide the extra £6 or £7 per ton? On railways which were not in a condition to pay any dividend at all, if the capital account were closed, and rails were introduced which would eventually produce great economy, he was afraid the result would be equivalent to confiscation; for suppose some 10,000 tons of rails, at an extra cost of £70,000, were laid down, and this sum were to be taken out of the preference dividends, that would prevent their receiving any dividend for the time being; and that he would call confiscation.

Mr. T. A. Rochussen stated that the author of the paper had mentioned the mode of welding first brought into operation at Hörde, in Prussia. The Plan C (Plate 14) was first adopted in the year 1851, when the coal and mineral traffic had increased to such an extent, that the ordinary iron rail did not suffice to resist the increased weight. The puddling of fine-grained iron led to the puddling of steel, which not only was applied to rails, but it gradually became a staple manufacture of the country. About two years previously he had produced two rails manufactured according to that process; and only two or three days ago he had an opportunity of inspecting some of the same rails at Oberhausen, where they had borne a traffic of 42,000,000 tons. The rails weighed 56 lbs. to the yard, yet only one side was worn; the other was untouched, and these rails would probably not be turned for another six months. That welding process had been carried on now for more than seventeen years, and was still largely in operation; compound rails were used to a greater extent than both solid steel rails and solid iron rails together. The difficulty of welding was greater with Bessemer steel than with puddled steel; and it had been found necessary to increase the weight of steel in the slab, so as to throw the weld into the web, as represented by Plan A (Plate 14). This process was only applied to the Vignoles section of rail; since there would be no saving in having the reversible opposite head in steel, leaving simply the small piece of iron between. It was very difficult to get the iron web from the steel head in the old rails.

He thought that the fracture of American rails, which had been mentioned, was due in a great measure to their unfavorable section, which was too shallow.

The Hörde works, in Prussia, had gone further than introducing the weld of steel and iron. They had for a number of years made different systems of iron angle-bars, with steel heads suspended between them. One system, which he exhibited, had been used for some time on the Brunswick Railway, and was a most advantageous mode of supporting a limited amount of steel by a larger web of iron.

Mr. Benjamin Baker observed that, in testing an iron rail against one of steel, of lighter section, but of equal stiffness, care should be taken that they were representative rails of equal average quality; so that a hard steel rail might not be tested against a soft iron one. He thought engineers had ample data to enable them to predict what the durability of such rails would be. The maximum stress on the rails could readily be ascertained, since it would be equal and opposite to that on the springs of the engine, the varying deflections and corresponding pressures of which might be noted in the ordinary working of the engine, at different rates of speed, over various portions of the line; the stress being known, the strain and deflection might be accurately computed. The comparative stiffness of similar sections of steel and iron rails was known to average as 4 to 3, and the strength as 5 to 3. It followed from this that the stiffness of Mr. Fowler's 84-lbs. section, if rolled in iron, would be equalled by a steel rail of similar but reduced section, weighing 72½ lbs.; and the strength would be equalled by a 69 lbs. steel rail.

With the section of rail adopted by Mr. Fowler, at 5 ft. bearings, the solid rails bore a deflection on an average of 10½ in.; those with drilled holes only 2½ in.; while those with punched holes snapped with less than ⅜ths of an inch deflection. Those rails were manufactured by the Dowlais Company from tough steel, of exceptionally uniform quality, the tensile strength varying very little in any experiment from 35 tons per square inch; and the breaking weight applied at the centre of the 5 ft. bearings averaged 29 tons for the solid rails, 19¾ tons for the drilled rails, and only 13½ tons for the punched rails. To break those rails in a testing machine, at the rate of 60 per min., would require 52 effective horse-power for the solid rails, and less than one horse for the punched ones; and the knocking about which the respective rails would sustain, without injury in ordinary working, would be nearly proportional to those amounts. The ultimate deflection of the punched rails was identical with that of cast-iron rails of similar section; hence, in one sense of the word, they were equally brittle. A curious fact, bearing upon the position of holes in the flanges of rails, was worth noting. In the rails above mentioned, the two holes at each sleeper were placed 4 in. apart, measured on the centre line of the rail, and on alternate sides of the web, so that the loss of section was that due to one hole only. Now theoretical considerations indicated that the resistance of the rail would be increased by making another hole opposite the existing one, notwithstanding the double loss of section. It seemed rather an odd way of strengthening a rail, to punch a hole 1⅛ in. diameter through its weakest part; but after making every correction, theory indicated a gain of 10 per cent., and this result was corroborated by direct experiment. It was found upon trial that, whilst with one punched hole the rails broke under 13½ tons' pressure, with two holes, placed opposite each other, of similar size, they sustained 14½ tons.

[TO BE CONTINUED.]

THE EAST RIVER BRIDGE—CHIEF ENGINEER'S REPORT.

To the Hon. HENRY C. MURPHY, *President N. Y. Bridge Company.*

SIR,—I have the honor to present the following report of the operations on the East River Bridge during the past year:

On the Brooklyn tower the masonry has been carried up within 20 ft. of the roadway, and is progressing steadily.

On the New York side the whole winter season has been occupied in sinking the caisson for the New York tower.

In the month of May a satisfactory foundation was reached at a depth of 78 ft. below mean high water, just one year since the launch of that caisson. The operation of filling the air chamber is now rapidly progressing. When this is completed, work will be resumed on the masonry, which is at present 4 ft. above high water.

To such of the general public as might imagine that no work had been done on the New York tower, because they see no evidence of it above the water, I would simply remark that the amount of masonry and concrete laid on that foundation during the past winter, under water, is equal in quantity to the entire masonry of the Brooklyn tower visible to-day above the water-line.

I also take this opportunity of congratulating the Board of Directors on the success which has attended the last of the two great tower foundations of the East River Bridge. At the commencement of the enterprise they constituted the principal engineering problem to be overcome, and not till they were accomplished facts could it be said that the project of the bridge was placed upon a firm, immovable footing.

The subsequent building of the towers and of the superstructure is all work that has been done before on a smaller scale, but upon the tower foundations rests the stability of the entire work. The whole enterprise depended on their success. Considerable risk and some degree of uncertainty was necessarily involved in their construction.

These have all been overcome, and when we see the New York tower rising above the waters of the East River this summer, the people of the two cities will acquire increased confidence in the early realization of a work so essential to their mutual prosperity.

THE NEW YORK FOUNDATION.

The last annual report contained a very full and detailed description of the sinking of the Brooklyn caisson. The account of this work, as well as of other large works executed elsewhere, has made the operation of caisson sinking familiar to all.

It is therefore proposed to touch only upon such points of the New York foundation wherein it differs materially from the Brooklyn foundation.

BORINGS.

The borings made heretofore on the site of the New York foundation had been confined only to the small area covered by the old pier 29. It was very desirable to continue them over the remaining portion of the foundation as soon as the adjacent ferry slips were vacated.

This occurred at so late a day, that only four more boreholes could be put down before the caisson was ready for sinking.

The knowledge derived from nine small boreholes was therefore the sole information we possessed of an entire area of 17,500 sq. ft. These holes being moreover confined to the outer edges, left the central portions a *terra incognita*.

The results showed an extreme difference in the level of the bed rock of 12 ft., the hole of the least depth touching rock at 80 ft. below high water, and the deepest at 92 ft.

The strata consisted in the main of a black mud deposit of 12 ft., followed by a layer of coarse sand of 6 ft., which overlaid a gravel bed of the same thickness. Beneath the gravel appeared a very heavy deposit of quicksand, varying from 15 to 20 ft., according to locality, and abounding with boulders in its lower portion.

This quicksand extended usually to within a few feet of the rock, and in some instances to the rock itself. But the immediate rock surface was covered with a compact layer of material through which it was impossible to drive a 6-in. pipe without shattering it. To drive the pipe one inch only required thirty blows of a 500-lbs. hammer, falling from a height of 20 ft. But even in such material the quicksand would run into the pipe from below, and fill it up for several feet.

When the sinking of the caisson commenced, this question still remained undecided, whether to go to rock or remain above it.

In case of the former alternative, we had the means at hand for blasting the entire rock to a level surface if necessary, and of removing the blasted material, at an additional expense, it is true, of several hundred thousand dollars and six months more time.

Or, in case the material on the rock proved water-tight, it would be feasible to sink a requisite number of small foundations to the bed rock sufficient to hold the immediate weight above, and then, by a series of smaller coffer-dams or cylinders, remove the remainder of the material, and thus get a uniform mass of material between the rock and the roof of the air chamber.

The only course therefore left open under the circumstances was to proceed with the work, and, when the caisson had arrived within a short distance of the rock, make a sufficient number of soundings, and then determine upon a course of action when we were face to face with the material.

The character of these boreholes had also made it apparent that any single plan of operations would not be adequate for removing all the material we would encounter. The immediate river bed consisted of logs and loose dock stones, followed by a sticky, black clay. These materials could evidently be best removed by dredges working in water shafts.

The river sand and firm gravel beneath would be easier removed through pipes, either by pumps or the air pressure direct.

The coarser gravel, however, would go to the water shafts; whereas the fine quicksand would again be blown out through pipes, until the preponderance of boulders and small rounded stones compelled a recourse to the water shafts again, provided any dredge whatever had the capacity to remove stones imbedded in quicksand.

For a direct removal of material through locks no special means were deemed necessary beyond the ample facilities afforded by four capacious air locks already at hand.

PREPARATIONS FOR SINKING THE CAISSON.

Owing to the vexatious delays in obtaining possession of the ferry slips adjoining Pier 29, nothing of any importance could be done in the matter of locating machinery or workshops until August, when the ferry boats finally ceased running into their old

slips, and the new boundary line was established between the property of the Ferry Company and the Bridge Company.

The month of August and part of September were employed in building a pile dock from the bulkhead line out to the caisson, averaging 450 ft. in length and 180 ft. in width.

At its outer end was formed a square inclosure, open on the river side, for the purpose of receiving the caisson when it was ready to be towed up from the Atlantic basin.

The amount of space on the pier line was so scant, that a narrow platform of 10 ft. width constituted all the available room between the sides of the caisson and the fender rack of the ferry on the one side, and the crowded shipping of the adjoining slip on the other, showing that economy of space during erection is not the least of the merits of caisson foundations.

INCLOSURE OF CAISSON.

For the purpose of obtaining still water, the caisson was surrounded by a wall of sheet piling, composed of white pine planking 50 ft. long and 6 in. thick. This served to break the force of the tidal current, which often runs at the rate of four miles per hour, and would produce a pressure of 90 tons against the structure at a time when it is most important to have it stationary in its true position—just before touching bottom.

This entire work of pile driving and dock building was superintended in the most efficient manner by Mr. George McNulty.

Within the inclosure thus formed the bottom was dredged to a uniform level of 37 ft. below high water, by means of the clam shell dredge of Messrs. Morris & Cummings, who did this portion of the work under contract.

They removed in all 7,000 yards of material, of which 1,500 yards consisted of dock stone and logs.

MACHINERY AND WORKSHOPS.

On the pile platform thus prepared were erected two engine houses for the dredge machinery, which was transferred from the Brooklyn side, and had been enlarged to correspond to the increased depth to which this caisson would go.

Two double hoisting engines were set up, both for unloading stone and setting stone on the caisson.

Four additional double engines were provided for unloading sand, gravel, coal, cement, and lumber, for hauling dredge cars back and forth, pumping gas and mixing concrete.

The principal building, however, was the

COMPRESSOR HOUSE,

for supplying air to the caisson.

The air pumping machinery comprised thirteen of the Burleigh rock drill air compressors, ranged in a single row; each discharging its air into one common ten-inch main overhead, and provided with suitable valves to shut it off from the main system.

Every compressor has its own steam boiler of the vertical tubular type, so connected as either to work independently or as an entire set. Pumps for cooling the air were also in duplicate.

Six of these compressors were brought from the Brooklyn caisson, the remaining seven being purchased anew.

From the compressor house the air was carried by a ten-inch cast-iron pipe through an intermediate air reservoir, for a distance of 150 ft. under the dock, to the caisson, whence two branches of six-inch rubber hose continued it by means of the supply shafts to the air chamber below.

The idea governing the general arrangement of the air pumps was the necessity of an uninterrupted supply of air, day and night, for at least a year, under a constantly increasing duty.

This could only be done by a number of smaller machines, so that if one were out of repair the remainder would have sufficient capacity for the work.

Besides the buildings for machinery and offices, a number of sheds were erected for the accommodation of blacksmiths, carpenters, machinists, for cement and for general stores, also wash rooms, clothes houses, hospital, and resting rooms for the caisson men.

Three unloading derricks, a double railroad track, and two overhanging platforms comprised the preparations on the dock for supplying the caisson derricks with stone.

TOWING THE CAISSON INTO POSITION.

All preparations for receiving the caisson being completed by September 11, it was on that day towed from the Atlantic basin to its final resting place. While at the basin seven additional courses of timber and concrete had been built upon it under con-

tract with Mr. D. Burtis, Jr. All the outer seams were caulked and protected by felt, tin, and creosoted sheathing. The various pipes, shafts, and locks were also carried up the necessary height.

This work was very carefully attended to under direction of Colonel Paine.

Four air pumps and boilers placed on the deck served to inflate the structure during the voyage. Its draft of water when empty was 23 ft., reduced by inflation to 17.

Total weight 7,000 tons.

Under the skilful guidance of Capt. Murphy, and the assistance of six tugs, the trip was safely performed in two hours and a half. A few days' work then sufficed to complete the pile enclosure and confine the New York caisson in its permanent position.

ADDITIONAL TIMBER COURSES.

By the 1st of November the last of the timber courses was laid under the Burtis contract.

The great timber foundation was now completed. It contains 22 ft. of solid timber above the roof of the air chamber, seven courses more than the Brooklyn caisson, and since the strength of such structures varies as the square of the depth, we may consider it to be nearly twice as strong as its Brooklyn brother. The result has proved this. At a depth of 78 ft., and a load on its back of 53,000 tons, not the slightest sign of weakness or crippling has been discovered. No deflection has been observed in the roof, even when the main frames and edges below were entirely dug out and not resting on the ground. The principal object of these frames is at most a precautionary one, besides serving to fill up the air chamber to the extent of their bulk.

OUTER COFFER-DAM.

An outer coffer-dam has been carried up outside of the masonry. It is composed of upright posts 12x12 placed 4 ft. apart, with an outer planking of white pine 6 in. thick. Shores extend from each post to the masonry, arranged in tiers for every three courses of stone.

The coffer-dam commences 7 ft. below the upper course of timber, where it is attached to the caisson by a heavy creosoted sill and screw-bolts. The space between it and the timber is filled with concrete, 14 ft. in height, beneath which the outer covering of tin extends for 5 ft. The upper layer of timber is covered with 3½ ft. of concrete, amounting in all to 3,500 yards.

Under certain circumstances it would have been possible to omit this outer coffer-dam and save the considerable expense attending it. On the Brooklyn foundation no outer coffer-dam was used, the depth of water being too shallow.

In any case it was necessary to carry up the dam for a height of 25 ft. When the last course of timber was laid, the caisson was still floating 2 ft. from the bottom at low water, and 10 ft. at extreme high water. To keep it on the bottom at extreme high water required four courses of masonry, and when inflated with air, three additional courses were required.

Owing to the rise and fall of the tide and the great top weight of the structure, the requisite buoyancy and stability could only be attained by the displacement of a coffer-dam, especially as the usual appliances of suspended screws, for keeping the structure level when afloat, were obviously inapplicable.

It had also been intended to surround the tower by a permanent dock of stone and concrete, the foundations of which could now be laid within this coffer-dam at a moderate expense. This intention was, however, abandoned, owing to the necessity of strictly confining the expenditure of money to the bridge proper. At present the coffer-dam has been designedly filled up with sand, and forms part of the timber dock extending to the tower masonry.

It will last for fifteen years without renewal.

The coffer-dam also formed a protection to all the caisson pipes, and made it possible to repair them when out of order.

These pipes consisted of four supply shafts of 2 ft. diameter and sixty pipes of 4 in. and 3½ in. None of them were built in the masonry, but came up between the wall and the coffer-dam.

On one occasion, through the accident of a large stone falling, a supply shaft was broken off at the timber line, and would have been lost but for the coffer-dam. But the chief benefit derived from it was the fact that the masonry was laid below the water level during most of the winter. The work of sinking the caisson could therefore proceed uninterruptedly, no matter if the masonry stopped on account of the cold weather.

INNER COFFER-DAMS.

Two smaller inner coffer-dams served as a water-tight lining to the main well holes of the masonry. Within them were carried up the sections of water shaft, as well as the curbing of the air lock shafts.

As far as the timber extends, this curbing consists of a boiler-plate shell, stiffened by flanges and secured to the timber by wood screw-bolts. The wooden curbing of 6 in. plank was notched, dowelled, and caulked, and further protected on the outside by a ring of concrete between it and the inner coffer-dam. The leakage has been practically none.

DERRICKS AND MASONRY.

The stone were laid by three boon derricks, similar to those employed on the Brooklyn foundation. They were guyed solely from the caisson itself, so that the settling of the latter did not disturb the guys. Every 20 ft., the derricks had to be raised, an operation requiring a few days.

Twenty-five courses of stone have been laid on top of the timber, making a height of 50 ft., and amount in all to 11,700 cubic yards of masonry.

The stone are all bedded down to a uniform rise in one course, with joints dressed down to moderate projections, the rises varying from 20 to 30 in. Both granite and limestone were used indiscriminately, the former coming principally from Maine, and the latter from Kingston, Lake Champlain, and Canajoharie.

Owing to the early commencement of winter, much of the stone in transit for the New York Tower was frozen in, and, in order to keep on setting, it became necessary to use all the backing intended for the Brooklyn Tower. This has been supplied since, and at no time has there been any stoppage for want of stone.

During the severest weather work was suspended for several days at a time, the coffer-dam preventing the river from covering the wall.

WORK IN THE AIR CHAMBER.

By the end of November sufficient weight had been placed on the caisson to prevent its rising for a short time at low tide when inflated.

A gang of laborers commenced work for several hours every day, taking up the floor of the air chamber and removing the principal obstructions in the shape of dock logs and stones under the edges and frames.

In proportion to the weight above, the length of time spent below was increased, until two regular gangs were at work, four hours on and four hours off, the caisson being now permanently grounded.

Each gang consisted of about seventy laborers and seven foremen. In a short time an extra night gang was also established. Two weeks were consumed in removing and taking out the floor.

This floor proved a valuable adjunct in giving the caisson a level bed on which to rest, and in preventing it from tipping up on either end before sufficient weight had been placed on it.

The character of the work at this particular time was more disagreeable than at any subsequent period. This location had for many years been the site of the principal dumping ground for city garbage. The mud abounded in decaying animal and vegetable remains. Although the odor of these was checked while imbedded in the salt water mud, it came forth in its original strength when brought in contact with the caisson air. More men were overcome by foul air than by compressed air.

By keeping the material constantly covered with water, so as to cover the odor, it was gradually disposed of through the water shafts.

This black dock mud is really a clay, and is the silt brought down by the North River, merely lacking time and pressure to make it as hard and tenacious as ordinary clays. It derives its black color from sewer discharges, but is by no means their product.

The coarse river sand and beach gravel beneath the mud soon created a change for the better below. The water was easily expelled by the air, leaving it dry under foot.

By this time also the gas-lights were in complete operation in all the chambers, giving ample light in every part. Two coats of whitewash over the roof and walls aided in reflecting it and making the air chamber an agreeable spot compared with what it was at the beginning.

The performance of the

DREDGES

in the mud and coarse sand and gravel was very satisfactory. They constantly maintained a hole about 6 ft. in depth under the water shafts, and removed from 300 to 40 yards per day.

Water for the shafts was supplied by two sets of 4 in. pipes, one of fresh water from the city mains, the other connecting with a force pump on the dock, which threw in a constant supply of salt water under great pressure, and proved of considerable use subsequently in loosening boulders under the water shafts. Owing to the fact that the shafts were 50 ft. from the nearest edge of the caisson, a supply of water from the river without could at no time be relied upon.

THROWING OUT SAND THROUGH PIPES.

About fifty pipes were located in the roof of the caisson, passing up through the timber, and discharging above beyond the cofferdam. In size they varied from 3½ to 4 in.

The precise mode in which they were to be utilized in throwing out sand had been to a certain degree left undetermined. Two modes were applicable, either to throw out the sand by direct force of air, or else have recourse to sand pumps.

Very satisfactory experiments had been made the year before in the Brooklyn caisson, in throwing out sand through pipes by air pressure.

The same mode had been used ten years previously by Gen. S. Smith and Mr. C. C. Martin in blowing sand out of cylinders, and more recently at Omaha under similar conditions.

The apparatus is very simple, consisting merely of a piece of pipe and a through way cock extending into the air chamber.

Moreover the objection of a very small air space to draw upon, as is the case in pneumatic cylinders, would not apply in a large caisson, which constitutes a large reservoir in itself, and would retard any rapid fall of pressure.

Another strong reason in favor of the air process was this: an air chamber with an iron skin can be made practically air-tight, but a certain quantity of air must be thrown in per minute to keep the air fresh and fit to live in. This air would usually escape under the edges and do no work. Now, why not allow it to escape through pipes, and at the same time carry out sand with it, and not be wasted? There was ample air pump power, thirteen compressors having been provided, of which number four only were required to supply the leakage, but six to supply sufficient fresh air.

Any other mode, however, of sending out the material would require extensive provision of machinery, in the shape of pumps, boilers, and pipes, entailing an additional cost of at least $40,000, and difficult of application for want of the required space around the foundation.

In view of these considerations, it was first determined to give the air system a thorough trial.

The result has been eminently satisfactory. At a depth of 60 ft. sand was discharged through a 3½-in. pipe continuously for half an hour at the rate of one yard in two minutes. This represents the labor of fourteen men standing in a circle around the pipe and shovelling as fast as their strength would permit. At this depth the supply of air was sufficient to supply three pipes at a time. This may appear a small number compared with the whole number of pipes, but yet was enough to keep at least sixty men busy.

The labor in itself is very fatiguing, making frequent resting spells necessary; more hands are required to throw the sand to the pipes than to feed them, and a large proportion of labor is expended in digging out under the frames and edges.

The most economical mode of working these pipes was made the subject of many trials by Col. Paine and Mr. Collingwood, the engineers in charge of the caisson. Trials were first made with flexible pieces of hose provided with strainers at the end. These became choked too easily both in the holes of the strainer and in the hose. The strainer was then removed and a shorter piece of vertical hose used, in connection with a piece of iron pipe. This in turn was discarded for a stationary iron pipe, extending within a foot of the ground, and provided with a stopcock below the roof.

Around the lower end of this pipe the sand and earth were heaped up in the shape of a cone, while another workman attended to the opening or shutting of the air cock.

As the pressure increased, the lower orifices of the pipes were reduced to 3 in. and finally 2 in., the same quantity of material being reduced with a smaller loss of air.

The material, of course, passes out with tremendous velocity, stones and gravel being often projected at least 400 ft. high. When the feeding below was too slow or irregular, the sand would be thrown very high, but, by practice, the discharge soon became more uniform.

In order to deflect the sand at the top of the pipe at right angles, both wrought and cast-iron elbows were used at first. The sand blast would generally cut through these in an hour or two, sometimes in a few minutes, the thickness of iron being 1½ in. That portion of the elbow struck by the sand was then made open, and provided with a thick cap of chilled Franklinite iron, capable of being reversed when worn on one spot. These would at most last two days. Finally all elbows were taken off, heavy granite blocks placed over the mouth of the pipes, and the material discharged against them into the coffer-dam.

Several minor casualties occurred from the discharge of stones, such as a boatman on the river having his finger shot off and a laborer being shot through the arm by a large fragment.

Some inconvenience was experienced from the wearing out of the ends of the pipes below in the air chamber. The cocks also wore out rapidly, owing to careless attendance in not opening them all the way. The pipes in the timber did not wear. When a 4-in pipe had become cut, a 3½-in. pipe was driven inside of it, then a 3-in. and at last a 2-in. But they lasted so well on an average, that one-third of the pipes were never used.

QUICKSAND.

When the quicksand was fairly entered upon, it was found that the dredge buckets no longer operated to any advantage. This sand, in combination with small stones and boulders, will compact to a mass as hard as rock, which cannot be penetrated by the teeth of a bucket, and even the point of a crowbar can scarcely be driven into it.

Some slight relief was experienced by the use of a hose under the shaft to stir up the material, but even then the sand was so fine as to escape through the slightest crevice in the buckets.

The sand pipes became henceforth the sole reliance, and answered admirably, until the coarse gravel and stones became so plentiful as to choke the ends of the pipes, making it necessary to stop for a moment to remove the stone.

The work of the last 10 ft., from 68 to 78, was on this account very tedious and slow. Previous to this, the progress had at times averaged a foot per day of 16 hours, implying the removal of 650 yards per day, but toward the end this rate decreased to 1 or 2 ft. per week.

CUTTING OFF THE WATER SHAFTS.

At a depth of 68 ft. a number of boulders were encountered under one water shaft, too large to be removed either by the dredge or by outside appliances. It therefore became necessary to cap the shaft and blow out the water, similar to the operation so frequently performed in Brooklyn. On top of the cast-iron cap was placed one of the old air locks, so as to afford access into the shaft hereafter.

After the water was blown out and boulders removed, the shaft was cut off near the roof of the air chamber. The same process was repeated with the other shaft. During this time the caisson was kept from sinking by banking up the frames and edges with earth.

The air pressure against the caps of the shafts is 133 tons. The individual sections had been tested to twice this pressure before, but, by way of precaution, an additional dead weight of 50 tons was placed on them.

Where water shafts are used it is absolutely necessary to make provision for capping them.

SOUNDINGS FOR ROCK.

At a depth of 70 ft., soundings were begun in the air chamber for the location of the bed rock, by means of a pointed rod, 10 ft. long, driven in by sledges.

A trial was made to sound by means of a pipe and water jet, but was abandoned on account of the numerous stones. These probings were carried on daily for a month, until a clear idea of the form and depth of bed rock was attained.

The surface was evidently very irregular, composed of alternate projections and depressions, the extreme difference in elevations encountered being 16 ft., and occurring chiefly along the water edge. Throughout the central portion, however, and covering at least two-thirds of the entire area, the irregularities were much less, amounting to only 3 or 4 ft. in a length of 160, and width of about 75 ft.

The caisson would apparently settle on a broken ridge of rock, running diagonally from one corner to the other, and having a moderate dip of perhaps 5 ft. in the 100 toward the land; but falling off very suddenly toward the east corner in number one chamber.

With these facts before us, it was evident that it would be a matter of immense expense and great loss of time to blast down the rock to a comparatively level surface; but unless this were done it would appear equally dangerous to allow the caisson to rest on the rock at one end and not on the other.

Fortunately one circumstance put a more favorable appearance upon the case, and that was that the top of the rock was found to be covered for a depth of 2 to 4 ft. by a layer of very compact material, so hard that it was next to impossible to drive in an iron rod without battering it to pieces.

Moreover, where the rock lay the lowest, this layer of hard material had its greatest thickness.

It was good enough to found upon, or at any rate nearly as good as any concrete that could be put in place of it. In extent it covered fully three-fourths of the caisson, leaving a narrow strip of quicksand along the land edge, and a triangular portion over part of number one and six chamber.

Since the lower line of the quicksand sloped at the rate of 6 ft. in the hundred, it became necessary to penetrate about 5 ft. into the hard ground on the water edge, before the bottom of the quicksand was reached on the land side. The number of boulders found in it was very large, much greater than were found in the same space on the Brooklyn side.

It was determined to rest the caisson on this material at a depth of 78 ft. The projecting peaks of bed rock which already made their appearance at 75 ft., were blasted down for some distance under the shoe, and covered with a foot of compressible earth.

In number six chamber a trench was sunk through the remaining quicksand under the edge, and filled with concrete to confine the portion remaining within; a task of no small difficulty, owing to the influx of water and sand.

Any other small irregularities will be fully equalized by the great timber platform above.

BED ROCK.

The first spurs of bed rock were encountered at a depth of 75 ft., under the shoe on the water side. It would seem that the caisson had been scraping along a vertical wall of rock for the previous 5 ft. at that spot.

The rock is the ordinary gneiss found on Manhattan Island, with a dip almost vertical. No part of its surface shows the rounding action of water or ice. On the contrary, the outcrop is in the form of sharp thin ridges, with steep vertical sides occurring in parallel ranges.

On such a bottom no sliding can ever take place, no matter what the average slope might be. At 78 ft. the outcrop was struck in a number of places and blasted down a short distance below the edge. A slight covering of soil gave the necessary amount of compressible material above these rocky points. Nearly all of them occurred under the edge on the water side, a favorable circumstance, since the resultant of pressure is in that direction. No fresh water was found on the rock, but salt water entered upon a reduction of air pressure.

FILLING OF THE AIR CHAMBER.

The concrete for filling the chamber is all mixed above and let down through the supply shaft ready for distribution below.

No brick pillars were used as under the Brooklyn caisson, the bearings of the frames being so wide as to be equal to all contingencies when once uniformly packed under with concrete. The stones, earth and sand left in the caisson during the sinking were sufficient to fill one-third of the space, and since the concrete is going in at the rate of 80 to 100 yards per day, it is probable that the chamber will be filled in the early part of July. Final exit will be had by the water shafts.

EFFECTS OF THE COMPRESSED AIR ON THE MEN.

These were not so serious as first anticipated. The few cases of death that occurred could in but two instances be charged to the effects of the pressure.

As the latter increased, the working hours below were gradually reduced from four hours to two hours, twice a day, at 35 lbs. It is true that scarcely any man escaped without being somewhat affected by intense pain in his limbs or bones or by a temporary paralysis of arms and legs; but they all got over it, either by suffering for a few days outside, or by applying the heroic mode of returning into the caisson at once, as soon as the pains manifested themselves.

The shortening of the hours of labor produced the best results in keeping the men in good condition; but even this was not necessary for all constitutions, because some

could remain below with impunity for six hours at the highest pressure.

After the locks were passed the men had their choice of coming up either by an elevator or by circular stairs.

During the winter months all tendency tocongestion of the lungs, owing to the sudden change of temperature in coming out of the locks, was controlled by means of steam coils in the latter, so arranged as to warm the air when coming out of the lock and to cool it when passing in.

The general condition of the air below was very pure, due to the absence of candles, and illumination by gas alone.

Mr. Collingwood found that as the pressure increased, the gas-burners gave more light, and at 35 lbs. a 1 ft. burner gave as much light as a 4 ft. burner outside. We therefore had a maximum production of light with a minimum production of irrespirable gases.

The services of Dr. A. H. Smith were engaged for the purpose of attending to all caisson cases and examining new candidates for work below. He has been quite successful in his treatment, and it is to be hoped that his experience will be made public for the benefit of future works.

The fact remains, however, that the effects of compressed air on the human system constitute the principal difficulty attending deep pneumatic foundations. Men are somewhat difficult to get, wages are high, and the time of labor becomes so short that the work must necessarily be done under a disadvantage, and under an immense amount of supervision, where it is at all difficult or different from ordinary digging in a uniform material.

Besides two general foremen and fifteen under-bosses, it required the daily attendance of both Col. Paine and Mr. Collingwood, assisted occasionally by Mr. Martin and Mr. McNulty, to keep matters moving smoothly below and in conjunction with affairs above.

An ingenious mechanical telegraph, contrived by Col. Paine, proved of great assistance in keeping up communication between the upper and lower world.

LIGHTING THE CAISSON.

The ordinary street gas has been the only agent used for illumination. Sixty burners, divided among the six chambers, gave all the light required. The gas was burned under a pressure of 1 or 2 lbs. in excess of the caisson pressure, and was at all times uniform and plentiful in supply.

In order to maintain a uniform overpressure of the gas below, independent of the sinking of the caisson, a strong cylindrical tank, 6 ft. long and 3 ft. in diameter, was placed in the air chamber. This communicated by means of a water pipe with another tank of the same size on the dock, several feet above the water level. A column of water was thus established, having a head always a few pounds in excess of the caisson pressure, and capable of forcing the gas out of the lower tank into the air chamber.

A gas pump above, forced the gas steadily into the tank below, and as the latter would fill with gas, it raised the column of water in the tank above, where, at a certain stage, a float controlled the throttle-valve of the gas pump, and thus regulated the supply of gas within restricted limits, the whole arrangement being self-acting.

One interesting fact was observed, which may possibly be new, and that is, that in compressed air all gaslights become sensitive flames, answering to the stroke of a hammer on a piece of iron, or even to tones of the voice.

MOVEMENTS OF THE CAISSON.

The downward movement of the caisson has been under perfect control throughout the whole of the sinking. It usually occurred at low tide and was very gradual, owing principally to the wide frames and broad shoe.

While the caisson was passing through the mud, river sand and gravel, the frames sank through the material without digging; but in the quicksand and harder material below, the whole frames had to be dug out underneath before settlement would take place.

The caisson also sank perpendicularly in its true place, no movement occurring in any direction. This result was principally owing to the facility with which it was kept level by digging.

The side friction was considerable, but difficult to estimate, because the frames and shoe were seldom entirely clear It could not have been less than 600 lbs. per sq. ft. of external surface, varying with the amount of air passing out under the shoe.

The total resistance offered by the side friction is, however, quite small when compared with the total bulk. At a depth of

78 ft. the side friction amounted to 6,000 tons, whereas the weight of the whole foundation, including masonry, was 53,000 tons.

At 78 ft., the excess of the downward pressure of the caisson over the upward pressure of the air at low tide would average from 10,000 to 12,000 tons, not including side friction. The air pressure has, however, frequently run so low as to give an excess of downward pressure of 15,000 tons. An excess of overweight is in all cases an advantage, as it saves considerable digging.

The experience with this foundation goes to show that a larger caisson is much easier to handle, is safer and under more perfect control than a smaller one. The labor question, however, becomes the most serious drawback where a considerable number of men have to be brought together under abnormal circumstances. The forces of nature may be measured and brought under control, provided they are properly understood, but human nature is not so amenable to laws.

THE BROOKLYN TOWER.

The work of laying masonry on this tower has progressed steadily. Seventy-five feet in height have been laid since June 1, 1871, amounting to 9,300 yards of masonry. Twenty feet more are required to bring it up to the level of the roadway.

Below the roadway a number of heavy steel and iron bars will be set in the masonry for a variety of purposes. They comprise six sets of cast-steel bars, 10 by 2 in., and 60 ft. long, passing around the outside of the tower, between the masonry courses, and serving as an attachment for the main under-floor storm cables.

In addition, there are sixteen sets of cast-steel bars passing through the connecting walls and into the main buttresses. To these will be attached the six lines of trusses of the bridge as well as sixteen counter-stays to the cables.

The iron bars comprise four smaller sets for under-floor stays and twenty sets of long tie bars to be laid in the connecting walls below the floor. They are all galvanized as a protection against rust. The steel bars were made by the Butcher Works, of Philadelphia; the others at Phœnixville.

All the stone required to complete the masonry to the roadway are on hand, and at no time has there been any interruption in the work for want of stone.

The laying of stone was continued during a portion of the cold weather in December last, with a view of bringing the masonry to a certain stage where the winter months could be utilized in removing the old boom derricks and putting up a new set of hoisting machinery.

By a plentiful use of hot water and salt, this portion of the wall has been laid equally as well as the rest, especially as that proportion of the wall occupied by the cement and concrete amounts to only one-tenth of the whole bulk.

NEW DERRICKS.

The difficulty of guying ordinary boom derricks at the water edge at an elevation of 80 ft., becomes so great that another arrangement of stone hoisting and stone setting machinery was accordingly prepared during the summer of 1871, and put in position during last winter. These new derricks will lay all the masonry to the top of the tower.

The arrangement in general consists of three balance derricks, one in the centre of each shaft. Each derrick stands on a turn-table, 6 ft. in diameter, provided with conical rollers, and having a safety tail extending to the turn-table into the well-hole below.

The weight of the stone is balanced by a weight of pig iron, run in or out on the opposite boom as occasion may require. The setting of the stone is done by two small steam engines attached to the mast of each derrick, steam being led up to the tower from a boiler in the yard below. The derricks are raised, course by course, by means of hydraulic jacks.

Their chief merit consists in their absolute safety, there being no possibility of one falling over. With the boom derricks, however, there are numerous guys with hundreds of connections, any one of which giving way may involve the downfall of the whole system.

Such an occurrence took place last October, when by the giving way of a defective weld, two derricks fell, resulting in the death of three men and wounding of five others.

In connection with the setting derricks is a double system of stone hoists, consisting of two railroad tracks, always at a level with the top of the wall, and two hoisting frames. The stone are raised at a single lift by an endless rope, operated by an en-

gine and powerful machinery in the yard below.

Stone weighing seven tons are raised at the rate of 100 ft. per min., and are supplied as rapidly as the setting derricks can dispose of them. These tracks are raised every 4 ft.

The general arrangement is essentially the same as that used in building the towers of the Cincinnati Suspension Bridge.

THE ANCHORAGES.

Both towers being fairly under way, I would recommend the early acquisition of the ground required for at least one anchorage, so as to make a beginning this season, and utilize the coming winter by putting in the foundation.

The quantity of masonry in one anchorage is about the same as in a tower, although of a less costly character and more easily put in place.

Both the towers and the anchorages have to be completed before any thing can be done with the necessary preparations for cable making.

CONCLUDING REMARKS.

The pleasant task remains yet of expressing my thanks to the gentlemen who have so ably assisted in the prosecution of the work, and to whose untiring industry, constant watchfulness, and sound judgment is mainly due the success which has attended it to the present time.

The work in the caisson has been carried on under the daily supervision of both Col. Paine and Mr. Collingwood, relieved at times by Mr. Martin and Mr. McNulty, whenever the outside duties of these latter gentlemen would permit.

The labor below is always attended with a certain amount of risk to life and health, and those who face it daily are therefore deserving of more than ordinary credit.

The general foremen below have been Messrs. Creen, Young, Woliver, O'Malley, and Korner, assisted by twelve underforemen.

The masonry, carpentry, and machine departments have, as usual, been most efficiently attended to by Messrs. Douglass, Farrington, and Smith; while the draughting room has been in charge of Mr. Hildenbrandt, and occasionally Mr. Vonder Bosch.

To Mr. Horatio Allen, consulting engineer, my acknowledgments are due for his continued counsel and advice.

In regard to the relations of the engineering department and the general management, it gives me pleasure to bear testimony that all requisitions from the engineer department have been met with the utmost promptness, both in respect to quantity as well as quality, and that the relations of the different executive branches have been conducted with a mutual co-operation, conducive to the highest results, both in efficacy and economy.

Respectfully submitted.

W. A. ROEBLING,
Chief Engineer N. Y. Bridge Co.

A NEW THEORY OF THE DISCHARGE OF GAS AND STEAM FROM ORIFICES.

(*Continued from p. 16.*)

Equation (15) gives the living force of a unit weight of fluid passing the orifice

$$h = \frac{k}{k-1} p_2 v_2 \left(1 - \frac{p_1 v_1}{p_2 v_2}\right)$$

combining with (7) and (25)

$$h = \frac{x}{x-1} p_2 v_2 \left(1 - \left(\frac{p^1}{p_2}\right)^{\frac{n-1}{n}}\right) \quad . \quad (26)$$

But

$$\left(\frac{p_1}{p_2}\right)^{\frac{n-1}{n}} = \left(1 - \frac{p_2 - p_1}{p_2}\right)^{\frac{n-1}{n}}$$

Expanding by the binomial theorem, and using only the first terms of the series for small values of $p_2 - p_1$, we have

$$\left(\frac{p_1}{p_2}\right)^{\frac{n-1}{n}} = 1 - \frac{n-1}{n} \cdot \frac{p_2 - p_1}{p_2}$$

Substituting in (26)

$$h = \frac{x(n-1)}{n(x-1)} v_2 (p_2 - p_1)$$

or combining with (22)

$$h = \frac{v_2 (p_2 - p_1}{1+\zeta} \quad . \quad . \quad (27.)$$

and this is the exact equation heretofore employed for the case of efflux under slight difference of pressure. It follows that ζ, for such difference, assumes the value heretofore given in the tables for efflux of air.

It is to be remarked that equation (27) holds for ordinary fluids, as water.

Regarding water as practically non-expansive, the pressure-curve $U_2 U_1$ (Fig. 3*a*)

nearly coincides with the vertical $U_2 v_2$; v_1 is nearly identical with v_2 and the hatched surface is approximately rectangular, hence

$$h + w = v_2 (p_2 - p_1)$$

and putting $W = \zeta h$, we have equation (27). These equations are usually employed with the substitution of the density γ (weight of the cubic unit); hence

$$h (1 + \zeta) = \frac{p_2 - p_1}{\gamma}$$

and from (22)

$$\frac{n-1}{n} = \frac{x-1}{x(1+\zeta)}.$$

Assuming that the adiabatic curve $U_2 U_0$ (Fig. 3*a*) forms a vertical straight line, $k = \infty$,

$$\therefore \frac{n-1}{n} = \frac{1}{1+\zeta}$$

and instead of (26)

$$h = p_2 v_2 \left(1 - \left(\frac{p_1}{p_2}\right)^{\frac{1}{1+\zeta}}\right)$$

which, for small differences, takes the form of (27).

From these formulas new principles may be deduced, to which reference will be made.

Suppose a very large vessel filled with water; that the pressure p_2 and the temperature T_2 are constant in the horizontal plane of the orifice; then the specific volume during efflux may be regarded as constant; then $d v = 0$, and equations (3) and (4) give for $Q = 0$,

$$h + W = (p_2 - p_1) v_2 \quad . \quad . \quad . \quad (28.)$$

and

$$W = U_1 - U_2.$$

The change of interior work or heat of water I consider as proportional to the change of temperature. Hence if the water passes through the orifice with the temperature T_1, $c = 1$ being the specific heat of water,

$$A W = c (T_1 - T_2)$$

The resistances at the orifice cause the water to pass the orifice with an increased temperature, which can be determined by calculation.

Since $W = \zeta h$ and $v_2 = \frac{1}{\gamma}$ we have from (28)

$$h = \frac{1}{1+\zeta} \cdot \frac{p_2 - p_1}{\gamma} \text{ and } W = \frac{\zeta}{1+\zeta} \cdot \frac{p_2 - p_1}{\gamma}$$

hence by preceding equation

$$T_1 - T_2 = \frac{A \zeta}{c(1+\zeta)} \cdot \frac{p_2 - p_1}{\gamma} \quad . \quad . \quad (29.)$$

It follows that $\frac{p_2 - p_1}{\gamma}$ signifies the excess of pressure measured by the water-column; if this is H, then

$$T_1 - T_2 = \frac{\zeta}{c(1+\zeta)} . A H \quad . \quad . \quad (30)$$

If the water is caught in a vessel the water comes to rest and a temperature T'_1 is taken up expressed in the equation

$$A h = c (T_1' - T_1)$$

From (31)

$$T'_1 - T_1 = \frac{1}{c(1+\zeta)} . A H \quad . \quad . \quad (31.)$$

From (30)

$$c (T_1 - T_2) = A H \quad . \quad . \quad . \quad (32.)$$

The whole work corresponding to H, is therefore contained in the water in the form of heat, and the work of resistance is not taken into account. The last formula may be found directly. Because p_2 is constant, the fluid unit takes up the work $p_2 v_2$ and gives out the work $p_1 v_1$ and as the fluid is at rest both at the beginning and the end of the process, it follows that $p_2 v_2 - p_1 v_1 = H$ must have been contained in the water as heat. These investigations are not rigorously exact, for it is assumed that the change of interior work is proportional to the change of temperature, and that water is absolutely non-expansive.

The differences of temperature as expressed in (30), (31) and 32), are entirely inappreciable for ordinary heads. In order that flowing water should receive an increment of 1 deg. Celsius it must be discharged under a pressure of a column of water of 424 metres.

(6.) DISCHARGE OF SATURATED STEAM.

In case of saturated steam the temperature is a function of p only, and is determined by experiments; while the specific volume is a function of the temperature t only, or of the pressure p. In the "Grundzüge" I have calculated the values for several cases, and have shown that the relation between pressure and volume is given with sufficient exactness by an empiric formula.

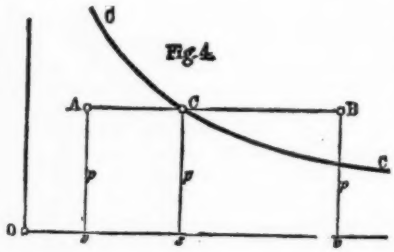
Represent the volume of the unit weight of saturated steam s, and the pressure in atmospheres by p; then

$$p s^m = M \quad . \quad . \quad (33.)$$

in which $m = 1.0646$ and $M = 1.704$, the pressure p being given in atmospheres.

Lay off (Fig. 4) s as abscissa and p as ordinate, thus constructing the curve C C, which we call the limiting curve of steam. Consider the curve as drawn and the values of p and v as given for a certain case; then there are three cases to distinguish.

If the corresponding point falls on the limiting curve, it is indicated that the steam is saturated and pure (without mixture with water); but if the point falls within the curve as at A, Fig. 4, in which case $v < s$, it is a proof that the steam is *wet*, *i. e.* mixed with water. Then the ratio of mixture, *i. e.* the specific quantity of steam, or the weight of steam in the unit weight of mixture, can be calculated from the given



volume v. The volume of the steam is $x\,s$, the volume of the water is $(1-x)\,\sigma$, σ being the volume of a kilogram of water, ($\sigma = 0.001$ cubic centimetres); hence

$$v = x\,s + (1-x)\,\sigma$$

or

$$v = x\,(s-\sigma)+\sigma \quad . \quad . \quad (34.)$$

$$x = \frac{v-\sigma}{s-\sigma} \quad . \quad . \quad . \quad (35.)$$

But if $v > s$ and the point B falls outside the limiting curve, it is shown that the steam is non-saturated or superheated; and the temperature T is higher than that of saturated steam or of a mixture with equal tension; and the relation between p, v and T is

$$p\,v = \mathrm{B\,T} - \mathrm{C}\,p^{\frac{k-1}{k}} \quad . \quad . \quad (36.)$$

For the steam from water $k = \frac{4}{3}$, and if p is given in atmospheres, B$= 0.0049287$ and C$= 0.187815$.

Suppose a mixture of steam and fluid as discharged under constant pressure p_2 into a space in which is maintained the constant pressure p_1; then equations I., II., and III. hold as well as the graphic illustrations in Figs. 3*a* and 3*b*. If heat is neither gained nor lost, and there is little resistance, then the problem is solved as in my "Locomotivblasrohr," p. 76. For the formulas there given may be substituted approximate formulas more convenient for application. In the "Grundzügen," it is shown that the equation for the adiabatic curve of saturated steam is approximately the same as that for gases: viz:

$$p\,v^k = p_2\,v_2{}^k = p_1\,v_1{}^k$$

in which

$$k = 1.035 + 0.1\,x_2 \quad . \quad . \quad . \quad (37.)$$

x_2 being the initial specific quantity of steam, and lying between 0.70 and 1.

It follows that all the formulas above deduced for permanent gases (with exception of those concerning the expansion of the steam outside the orifice) hold true in this case. In case of resistance, for the exponent k is to be substituted the efflux exponent n (eq. 22).

A numerical example will serve for illustration of these principles, and of the occurrence of certain peculiar phenomena in the efflux of dry or wet steam.

Let a boiler contain dry saturated steam of a tension of 4 atmospheres, which flows through a cylindric ajutage with well rounded edge, into free air. We have $x_2 = 1$, and by (37) $k = 1.135$. Suppose $\zeta = 0.1$; then by (22) $n = 1.1212$. From (33) and (34) $v_2 = s_2 = 0.4484$. At the left we set results for no resistance; at the right for resistance; the coefficients are

$$n = k = 1.135. \qquad n = 1.1212.$$

By (23) since $\frac{p_2}{p_1} = 4$,

$$v_1 = 1.5209. \qquad v_1 = 1.5439.$$

At the orifice there is a pressure of one atmosphere, and since the specific volume of steam of this tension $s_1 = 1.6504$ and both the preceding values for volume are less than this, it follows that the steam at the orifice is wet, and that a part is condensed.

The specific quantity of steam at the orifice is (35).

$$x_1 = 0.9215. \qquad x_1 = 0.9354.$$

It follows that in case of resistance a little less steam is condensed.

From (15)

$$h = 23687.6 \qquad h = 21692.8$$

hence by (19)

$$\mathrm{W} = 682.73 \text{ met.} \qquad \mathrm{W} = 652.391.$$

If the area of the orifice is expressed in square metres (F), then by (20) the weight of steam and water discharged in a second (with no contraction) is

$$\mathrm{G} = 448.2 \text{ F. kilog.} \qquad \mathrm{G} = 422.6 \text{ F. kilog.}$$

The weight D, of steam, is

$$\mathrm{D} = \mathrm{G}\,(x_1) = 413.0 \text{ F. kilog.} \qquad \mathrm{D} = 395.3 \text{ F. kilog.}$$

The quantity of water W is

$$\mathrm{W} = \mathrm{G}\,(1-x_1) = 35\ 2 \text{ F. kilog.} \qquad \mathrm{W} = 27.3 \text{ F. kilog.}$$

Outside the orifice the stream expands

under constant pressure; if r_1 = the temperature of the steam, and x'_1 the specific quantity of steam after expansion, then

$$A\,h = r_1\,(x'_1 - x_1) \quad . \quad . \quad . \quad (38.)$$

If $x'_1 = 1$ the steam is pure and saturated; if $x'_1 > 1$, then the steam has become superheated and the following equation applies

$$A\,h = r_1\,(1 - x_1) + c_p\,(t'_1 - t_1) \quad . \quad . \quad (39.)$$

in which C_p is the specific heat of the superheated steam under constant pressure. For steam of water put $C_p = 0.4805$ and find t'_1 and v'_1 by (36).

In the above example, since, according to Regnault, for steam at one atmosphere $r_1 = 536.5$, by (38) in both cases

$$x_1 = 1.0256 \qquad x'_1 = 1.0308,$$

which is impossible. Hence in both cases the steam in expansion passes to the superheated condition; and (39) must be employed. This gives, since $t_1 = 100°C$,

$$t_1' = 128.6. \qquad t_1 = 134.4.$$

From the foregoing considerations these values should be equal. The difference is explained by the fact that the formulas given for steam are only approximately correct, and that the constants found by experiment are not trustworthy. But certain experiments of Hirn confirm the above results; for the above case he found $t'_1 = 133°$.

Suppose in the foregoing example that the steam is not dry, but mixed with water, then assuming

$$x_2 = 1;\ 0.90;\ 0.80;\ 0.70;$$

we have

$$x_1 = 0.9354;\ 0.8504;\ 0.7637;\ 0.6753.$$
$$W = 652.4;\ 620.5;\ 586.5;\ 550.1$$
$$G = 422.6\ F.;\ 442.1\ F.;\ 465.2\ F.;\ 493.4.$$

Hence the quantity increases with the saturation.

Finally, it is to be especially remarked that according to the degree of the force of resistance, the steam may pass the orifice pure and saturated or in a superheated condition, although the same when in the discharging vessel may have been saturated with or without mixture with water.

For example, if the steam was dry and saturated before discharge, and is to pass the orifice in the same condition, the expansion curve should coincide with the limiting curve; therefore for water-steam the efflux exponent n should be identical with the value $m = 1.0646$; and since $k = 1.135$ we find the resistance co-efficient for the required orifice by (24) to be $\zeta = 0.9601$. Ordinary ajutages give no such large co-efficient.

(7.) THE EFFLUX OF SUPERHEATED STEAM.

In equation (36) is given the relation between pressure, volume and absolute temperature for superheated or non-saturated steam. This equation, since $k = 1.3333$, may be written

$$p\,v = B\,(T - \beta\,\sqrt[4]{p}) \quad . \quad . \quad (38.)$$

in which p is expressed in atmospheres. $\beta = 38.1064$ and $B = 0{,}0049287$. B has the same meaning as the constant R in the equation for gases, if p is measured in metre-kilograms.

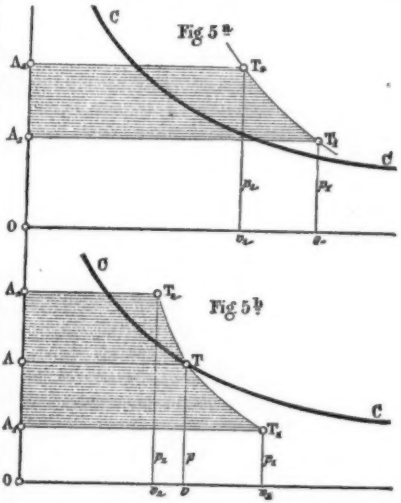
Then

$$B = \frac{c_p\,(k-1)}{A\,k} \quad . \quad . \quad (39.)$$

in which $C_p = 0.4805$.

The equation of the adiabatic curve for superheated steam is the same as for gases (17), according to our hypothesis; but for k is to be substituted the value given above. The isodynamic curve is also identical, being an equilateral hyperbola.

It follows that the above theory for efflux of gas holds for steam; still, two cases are special and require particular attention. If the steam is superheated in



the discharging vessel, it may, under certain circumstances, pass the orifice saturated and even mixed with water, if the expansion-curve cuts the limiting curve, which usually happens in case of slight superheating. In case of great superheating the steam passes in that condition. Figs. 5*a* and 5*b* represent

both cases. C C is the limiting curve; $p_2\ v_2$ T_2 and $p_1\ v_1\ T_1$ respectively show the condition of the steam in the discharging vessel and at the orifice; the curve $T_2\ T_1$ is the expansion-curve and the hatched portions show the value of $h + W$.

Ordinarily we have given p_2, T_2 in the discharging vessel and p_1 in the receiver; if ζ is given, the efflux-exponent is found by (22), putting $k = \frac{3}{4}$. Then from the equation $p_1\ v_1^n = p_2\ v_2^n$ (40) is found the specific volume v_1 at the orifice; v_2 having been found by (34). If v_1 is larger than the value corresponding to the volume s_1 of dry saturated steam at pressure p_1 by (33), it is indicated that the steam at the orifice is still superheated, and this case is represented in Fig. $5a$; the other, in which $v_1 > s_1$, when the steam passes wet, will be considered further on.

Suppose the discharging vessel to contain superheated steam at $p_2 = 4$ atmos., and $t_2 = 250°$ Celsius; and $T_2 = 523°$. Let the discharge pipe have a rounded mouth, so that $\zeta = 0.1$. Let $p_1 = 1$ atmos. or 10334 kilog. sq. met. From (22) $n = 1.2941$; from (38) $v_2 = 0.5780$; from (40) $v_1 = 1.6872$. Then by (38) the temperature at orifice $T_1 = 380.43°$ or $t_1 = 107.43$ Cels.; and since for dry saturated steam at one atmos., the volume $s_1 = 1.6504$, and the temperature is 100°, the steam at the orifice is somewhat superheated. By (15) $h = 25829.6$, and hence the true velocity. $w = \sqrt{2gh} =$ 711.88 metres, and for $a = 1$, G=421.9 F. We find the velocity much greater than for saturated steam at 4 atmos.; while the quantity is nearly the same; a result which is accidental.

The specific volume v_1' after expansion is found by (IVa) because the internal work is determined by the equation $p_1\ v_1' = p_2\ v_2$. Hence in the above example $v_1' = 2.3121$, and by (38) $t_1' = 261.2°$ Cels., or a little more than in the vessel.

As to the other case in which $v_1 > s_1$, the expansion curve also intersects the limiting curve; hence the steam leaves the discharge pipe mixed with water, although superheated in the vessel; so that the result is approximate only. The expansion curve breaks at the point T, and the hatched area consists of two parts; T_2 T being the expansion curve of the first, and T T_1, of the second. If k and n correspond to the adiabatic curve of the first (superheated), and k_1 and n_1 to the adiabatic curve of the second, we have the equation

$$h = \frac{x}{x-1}(p_2\ v_2 - p\ v) + \frac{x_1}{x_1 - 1}(p\ v - p_1\ v_1) \quad (41.)$$

in which p and v are the co-ordinates of T (Fig. $5b$) and v_1 is the volume of wet steam passing through the orifice.

If p_2 and T_2 are known v_2 is found by (38), and for the intersection we have

$$p\ v^n = p_2\ v_2^n \quad . \quad . \quad (42.)$$

But as this point is on the limiting curve (33) holds, and we have

$$p\ v^m = M. \quad . \quad . \quad (43.)$$

Then we have from

$$p_1\ v_1^{m1} = p\ v^{m1}. \quad . \quad . \quad (44.)$$

the volume v_1; h by (41); W, and G; as well as the ratio x_1 by (35).

Assuming $p_2 = 4$; $p_1 = 1$ atmos.; but $t_2 =$ 200 Cels. *i. e.* $T_2 = 473°$, then we have from (38) $v_2 = 0.5164$; $n = 1.2941$ and $n_1 = 1.1212$.

Combining (42) and (43)

$p = 1.7190$ atm. and $v = 0.9918$ cub. met.

From (44) $v_1 = 1.6079$. By (41) $h = 23340.1$.

$$W = \sqrt{2gh} = 676.71 \text{ metres.}$$

$$G = \frac{F\ w}{v_1} = 420.9\ F.$$

$$x_1 = 0.9742.$$

Hence there passes in a second $G\ x_1 = 410$ F. kilog. of steam and $G\ (1 - x_1) = 10.9$ F. kilog. of water. So the velocity is less, but the quantity nearly the same, as in the case when the steam is discharged superheated.

The method of calculation would be the same if resistance were left out of account. In that case $n = k$ and $n_1 = k_1$.

(8.) THE AREA OF ORIFICE.

In the foregoing investigations it was assumed that the pressure p_1 reaches exactly to the plane of the orifice, and that the stream does not suffer contraction. It is to be remembered that the pressure was not the same as in the receiver, but that equality occurred somewhere outside the orifice; in this case, in the above formulas F is not the orifice-section, but is that taken at this place, and is termed the efflux section. For orifices in a thin wall this section, as appears by Weisbach's new experiments, must doubtless be smaller than orifice-section; the ratio must be determined by experiments, and the result would be the contraction co-efficient. But if the efflux-section is assumed larger than the orifice-section, as seems possible in the case of certain ajutages, there is no contraction, but an expansion of the stream, giving an expansion coefficient $a > 1$.

The conjecture that the efflux-section under certain circumstances is greater than that of the orifice, was mentioned in my work "Ueber den Ausfluss von Dämpfen und hocherhitzten Flüssigkeiten." Rankine showed that this was the fact for certain shapes of orifice. He compares the results of our computations for dry saturated steam with those of Napier, and finds that experiments always give a larger quantity of discharge than was indicated by theory, and that the difference increases with the steam pressure in the supply vessel. Rankine calculates the expansion coefficient for several cases for dry saturated steam, and finds values which are especially large for high pressure; from which it was to be inferred that in such circumstances the efflux section was quite removed from the orifice. We are not acquainted with the results of the experiments of Napier; but from the fact that Rankine accepts them in his discussion, we conclude that they are trustworthy, and hence that there remains a point to be explained in the theory of efflux of gas and steam. The investigations heretofore made are not affected by the fact that they relate a new theory of the influence of resistances; the uncertainty consists only in the determination of the efflux section upon which the velocity and quantity must depend.

What remains to say in the present condition of the subject gives opportunity to touch upon a question treated by Rankine and Kolster, and to mention a slight modification of their treatment, because of the above results.

According to (15) the efflux of gas or steam is given by the formula

$$w = \sqrt{2g \frac{k}{k-1} (p_2 v_2 - p_1 v_1)}$$

And

$$G = \frac{a f w}{v_1}$$

$$\therefore \frac{v_1}{v_2} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$$

Combining and eliminating v_1

$$\frac{G}{F} = a \sqrt{2g \frac{k}{k-1} \frac{p_2}{v_2} \left[\left(\frac{p_1}{p_2}\right)^{\frac{2}{n}} - \left(\frac{p_1}{p_2}\right)^{\frac{n+1}{n}}\right]} \quad (45.)$$

A glance at this formula shows that there is a certain ratio $\frac{p_1}{p_2}$ for which the bracketed quantity is a maximum, so that if a is constant, G is a maximum. Differentiating

$$\frac{p_1}{p_2} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} \quad . \quad . \quad (46.)$$

$$\therefore \frac{v_1}{v_2} = \left(\frac{n+1}{2}\right)^{\frac{1}{n-1}} \quad . \quad . \quad (47.)$$

and

$$\frac{T_1}{T_2} = \frac{p_1 v_1}{p_2 v_2} = \frac{2}{n+1} \quad . \quad . \quad (48.)$$

For a given ratio of pressures the above equations give the efflux velocity and the quantity. The formulas agree in form with those of Rankine and Kolster, except that they use instead of n the exponent k of the adiabatic curve. Suppose, for example, that in the supply vessel is contained pure saturated steam, and that $\zeta = 0.065$; then by (22) $n = 1.1257$; and by the foregoing equations

$$\frac{p_1}{p_2} = 0.5793 ; \frac{v_1}{v_2} = 1.6240 ; \frac{p_1 v_1}{p_2 v_2} = 0.9408,$$

and the ratio of pressures

$$\frac{G}{F} = 195.5\, a \sqrt{\frac{p_2}{v_2}} \quad . \quad . \quad (49.)$$

in which p_2 is expressed in atmospheres.

If a is given, this expression would be the maximum of discharge, and if the steam is to flow into the free atmosphere the pressure in the vessel must be 1.726 atmos. For any other pressure in the vessel the quantity would be less, if a is constant.

Napier supposes a quantity of dry saturated steam discharged through a well-rounded adjutage. If $p_2 > 2\, p_1$ his formula is

$$\frac{G}{F} = 210 \sqrt{\frac{p_2}{v_2}} \quad . \quad . \quad (50.)$$

But if $p_2 < 2\, p_1$ it is

$$\frac{G}{F} = 420 \sqrt{\frac{p_1}{p_2}\left(1 - \frac{p_1}{p_2}\right) \frac{p_2}{v_2}} \quad . \quad (51.)$$

With regard to Eq. (50) it is to be remarked that it gives Eq. (45) under the hypothesis $p_2 > 2\, p_1$. Rankine infers that a varies in such a way that

$$a \sqrt{\left(\frac{p_1}{p_2}\right)^{\frac{2}{n}} - \left(\frac{p_1}{p_2}\right)^{\frac{n+1}{n}}}$$

is constant. I accede to this inference, but shall add a second which leads to important and simple principles, by which (45) gives Napier's results exactly.

Comparing the constant factor in Napier's equation (50) with (49), and assuming that the limiting ratio $\frac{p_2}{p_1}$ must be not 2, but, as in the case of dry saturated steam, 1.726; we conclude that a must be 1; that is, the efflux section equals the orifice section. But if this ratio is greater, then by (46)

$$a \sqrt{\left(\frac{p_1}{p_2}\right)^{\frac{2}{n}} - \left(\frac{p_1}{p_2}\right)^{\frac{n+1}{n}}} =$$

$$\sqrt{\left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}} = \sqrt{\left(\frac{2}{n+1}\right)^{\frac{1}{n-1}}} \sqrt{\frac{n-1}{n+1}}$$

from which a and a F can be found.

The following is simpler, giving the same result, but holds only for tubes and rounded orifices. We have

$$\frac{p_2}{p_1} = \left(\frac{n+1}{2}\right)^{\frac{n}{n-1}}$$

Now if the given pressure ratio is greater than or equal to the value found by the formula, then in (45) put $a = 1$, and for $\frac{p_1}{p_2}$ the value given by (46). Rankine's hypothesis also maintains that the pressure at the orifice can not fall below the value $p_1 = p_2\left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$, however small the external pressure, even in case of discharge into a vacuum.

In this case from (15) and (48)

$$W = \sqrt{\frac{2g \cdot k}{k-1} \cdot \frac{n-1}{n+1} p_2 v_2}$$

which is independent of external pressure.

Now if $\frac{p_2}{p_1}$ is less than the limiting value, then Napier's equation (51) applies. But I find that this equation is nothing more than the approximate formula of (45), if $a = 1$, and p_1 represents the external pressure. For example, if $p_1 = 1$ and $p_2 = 1.2$ or 1.4

$$\frac{G}{F} = 146.95 \text{ or } 200.83 \text{ kilog.};$$

while Napier gives as the results of his experiments 146.83 and 205.77.

We conclude that in the second case the external pressure p_1 extends to the plane of the orifice, and at either side the efflux section is identical with the orifice section.

For the efflux of gas and steam we obtain from the above the following rule. For tubes and well-rounded orifices the quantity from the formula (compare (45))

$$\frac{G}{F} = \sqrt{2g \frac{x}{x-1} \frac{p_2}{v_2}\left[\left(\frac{p}{p_2}\right)^{\frac{2}{n}} - \left(\frac{p}{p_2}\right)^{\frac{n+1}{n}}\right]}$$

without co-efficients of correction. The pressure at the orifice is indicated by p, and this is identical with p_1 if

$$\frac{p_2}{p_1} < \left(\frac{n+1}{2}\right)^{\frac{n}{n+1}}$$

otherwise

$$p = p_2\left(\frac{2}{n+1}\right)^{\frac{n}{n+1}},$$

and in this case the p is independent of the external pressure p_1.

There is hardly a well-grounded objection to the results of this investigation, though I have not reviewed the methods and examples of the earlier paragraphs, so much trust is to be put in the results of Napier's experiments, yet it is desirable to test the principles by experiments on atmospheric air.

The earlier experiments of Saint Venant and Wantzel on the efflux of air give results which seem to confirm our conclusions, but these were made with small orifices. For final settlement further experiments should be made. We are engaged with such, and shall return to the subject and examine the results of Weisbach so far as they refer to discharge under high pressure.

ON A NEW MODE OF DEALING WITH SEWAGE PRECIPITATES.

By MAJOR-GENERAL H. Y. D. SCOTT, C. B.

From the "Journal of the Society of Arts."

No class of doctors have differed more than sewage doctors, and the class has been recruited from widely different professions. Civil engineers, farmers, chemists, medical men, and clergymen have all had their nostrums, and each sewage doctor has thought his neighbor a quack. At length, however, there appear signs of meekness in the opposing ranks, and the sober-minded of each party, whether filtrationists, precipitationists, irrigationists, or disinfectionists, are listening with more attention to the views of their opponents, and beginning to conceive it possible that their own systems might receive aid from the adoption of portions, at least, of some of their enemies' schemes. The following propositions will not, I believe, be contradicted now by any but enthusiasts:

1. Though there are many cases in which the dry earth and analogous systems may be usefully employed, such systems are better adapted to country than to town life.

2. Large communities congregated in cities, and accustomed to the convenience

and cleanliness of water-closets, will not abandon the luxury if they can by any means retain it.

3. If the excreta could be disposed of by a dry-earth system of disinfection, the animal and vegetable matter, *e. g.*, cabbage water, the scourings of plates and dishes, and all the other impurities arising from the domestic operations of daily life, must be removed by water, and the water so used must be purified before it is allowed to run into our streams and rivers.

4. For the final purification of contaminated water, no artificial process, whether chemical or mechanical, can compare with filtration through a considerable depth of soil and of wide extent as compared with the water to be dealt with.

5. However valuable sewage may be to the farmer at such times as he may want it, if he be obliged to take it at all seasons, he will prefer being without it.

6. Whether sewage is to be utilized for purposes of irrigation or to be simply cleansed by filtration, it is advantageous to remove the fecal matters, either by subsidence, by filtration, or by precipitation, or by a combination of these methods.

7. Sewage is a comparatively harmless and inoffensive compound when fresh, but becomes highly offensive and deleterious when it has undergone putrefaction.

8. Putrefaction is greatly encouraged by the presence in the sewage-water of fecal matters, and their removal is, therefore, an important object, independently of the irrigation question.

9. The fecal matters of sewage have very little value as fertilizers, and in rare cases only can repay the cost of collection and distribution for agricultural purposes.

10. Such fecal matters cannot be collected and removed without creating a nuisance, unless they are previously treated with a considerable portion of deodorizing substances.

The use of water, then, would appear to be a necessary evil; and if it be granted that the civilized being will prefer taking the chance of poisoning his neighbor who lives lower down the stream to having his own senses of sight or smell, or his sentiment outraged, which would appear, by the frequency of injunctions, to be sufficiently proved; and if it is hopeless to innoculate the Englishman with the careful practice of the Chinese in respect of his excreta, it behooves us at once to endeavor to reduce the nuisance of water carriage to a minimum. The proposal which I have to lay before you this evening is an effort in this direction. My scheme makes no claim to the complete purification of sewage water, or to supersede irrigation or filtration, when these processes can be carried out, nor does it pretend to extract from the water those highly fertilizing but soluble substances which are known to exist in sewage. It aims simply at removing from it the fecal matters (which are injurious, whatever the destination of the sewage) by the cheapest possible precipitants, and subsequently converting what has proved worthless, as hitherto dealt with, into a marketable substance.

In all the schemes proposed for dealing with the deposit of sewage, the one idea hitherto has been to convert it into manure. The chemist may have demonstrated that the fertilizing ingredients of the deposit are in themselves almost valueless, owing to their being necessarily laden with an immense proportion of worthless matter; he may have shown that the deposit, though it may have increased value given to it by the introduction of fertilizers, gains its improvement in a very wasteful manner; but the idea still holds its ground, and within the last few days another sewage manure scheme has been announced to the public.

As early as 1861, the Sewage of Towns Commissioners stated that, "the value of the solid portions of sewage being small, all attempts at realizing profits from its preparation have signally failed;" and, in 1870, their successors, the Rivers Pollution Commissioners, express a similar opinion. They tell us that "experience has warned the manufacturer of these feeble manures that the value indicated by chemical analysis cannot be counted on in the market." Dr. Odling speaks of another sewage manure as "so extremely poor." Krepp says: "These instances are enough to prove that solids extracted from fluid sewage cannot be manufactured into dry manure so as to pay for the trouble;" and Mr. Corfield, the author of the "Treatment and Utilization of Sewage," gives his testimony that "the manures that they produce are in every case very inferior, as may be expected from the known value of the sewage constituents that can be precipitated." Nevertheless, sewage manure schemes prosper, showing this—if they show nothing more—that the object aimed at—viz., the satisfactory util-

ization of sewage slush, is one of the utmost importance to the community, and this must be my apology for bringing my own scheme before you this evening.

It must be conceded that the plan for dealing with the question which I am about to propose will, at first sight, appear even less calculated than the manure schemes to accomplish the desired object; but a very small amount of chemical knowledge, and a few words of explanation, will render the reasonableness of the process evident, and remove any objection which ignorance may raise to the employment of a material so prepared.

Before entering, however, upon the explanation of the process, I desire to call your attention to one feature of my plan of dealing with sewage, not *necessary* to the successful treatment of the sludge, but conducive to good results, and highly desirable from a sanitary point of view.

The attention of the public was forcibly called, towards the end of last year, to the evil results which may arise from the escape into our houses of sewer gases, generated by the decomposition of the organic matters in sewage; and any method which would tend to lessen the probabilities of the danger which the nation then incurred from this cause is well worthy of its attention.

In the precipitation of sewage, and for its deodorization, it has been the practice always to introduce the necessary chemicals at or near the depositing tanks, and to employ mixing machinery to agitate the chemicals with the sewage water to be operated upon. However perfect such machinery may be, the mixture, when large bodies of fluid are present, remains incomplete, and much of the material introduced passes off in the effluent water without doing its work. To obviate this, I have introduced the chemicals at a point of the sewer at a long distance from the outfall, and have taken advantage of the motion of the water to procure their thorough admixture with the sewage.

The first impression, when such a plan is proposed, is that the precipitation will take place in the sewer, and that an accumulation in the bottom of the drain of the precipitated matters must result, but this is not the case. On the contrary, the slimy glutinous nature of untreated sewage is destroyed by the precipitation, and in lieu of the slime we obtain a sort of curdling, and a multitude of small floating particles are produced, which actually clean and scour the drain instead of choking it. Thus it follows that no fecal matter is left to fester and putrefy on the sides and bottoms of the sewers, and the whole of the sewage is delivered at the outfall in a fresh condition, deodorized in the most effectual manner which the chemical employed can bring about. At Ealing, where this system is being carried out by my brother, Mr. T. W. Scott, subject to the supervision of Mr. C. Jones, the engineer of the Local Board, the results are very striking. The sewerage has two main branches, one from the railway station end of the village, the other from Ealing Dean, and the lime is introduced in the former one at a distance of three minutes' walk from the station and twenty minutes' walk from the tanks. In this branch the drain is clean throughout; from the Ealing Dean sewer, with each flooding from heavy rains, we get down a quantity of decomposing sewage, and the drain is found to be greasy, slimy, and coated with black deposit. Moreover, in the first drain, the formation of sewer gases being arrested by the rapid removal of matters which might otherwise putrefy, the atmosphere, of the drains is found to be so inoffensive as to occasion little annoyance to the workmen who visit them. The importance of these results cannot be over-rated, and this mode of introducing the chemicals has no less an authority in its favor than that of the President of the Civil Engineers, who recommends its adoption for Birmingham.

All processes for the precipitation of sewage depend for their efficiency upon a very simple action. Sewage, as has been said, is slimy and glutinous. Though the grosser particles in the liquid will subside on standing, the liquid will not clear itself unless a coagulation is produced in it which can lay hold of the solid suspended matters. The effect of adding chemicals which will unite with some substance in the fluid, or with each other, is to produce this coagulation. It thus happens that, with the mineral matter so formed, the whole of the fecal matters are entangled and subside, leaving the liquid more or less colorless and bright. These fecal matters consist in large part of organic compounds, which, when dried and distilled, yield great quantities of inflammable gases. In India, indeed, they have been used for illuminating purposes.

The dried slush will burn freely when collected in some quantity. This fuel plays an important part in my process, as will hereafter appear.

Various methods have been employed for the precipitation of sewage, and the mere enumeration of them would occupy more time than we have at our disposal. Many of them clarify and deodorize the sewage in a very satisfactory manner, but the expense of the chemicals necessary, and the worthlessness of the products obtained, have been a bar to their successful application. They have, consequently, one after the other, been abandoned, and have often been pronounced unsatisfactory, owing to the economical views of the governing bodies of the places which have tried them, and which have led to such a reduction of the chemicals used as entirely to vitiate the process. It is manifestly, therefore, of importance that the chemicals employed should be of the cheapest possible description; for in proportion to their value will be the likelihood of the recurrence of such economy when the slightest difficulty or delay arises in the advantageous disposal of the product; and this difficulty has been one of the worst drawbacks to every process yet tried. Of all the precipitating ingredients yet employed, lime has proved the simplest in application, and least costly. Dr. Letheby, writing in the medical press, observes on it: "In a sanitary point of view, the careful precipitation of sewage with lime has undoubtedly been very successful, although it has not been found a success commercially, for the precipitate is chiefly composed of carbonate of lime and non-nitrogenous organic matter." Wherever, indeed, this process has been fairly tried, a remarkable improvement of the neighboring streams has taken place. "The Tottenham Local Board of Health," says Dr. Letheby, "were so pleased with the process, that in the early part of 1857 they published a testimonial to the effect that Mr. Higgs was treating in a most satisfactory manner the sewage of from thirty to forty miles of sewers, and discharging the supernatant water in a comparatively pure state into the river Lea, so that the Board were thus enabled to sewer and drain their populous district without annoyance to anyone. At Leicester, also, in 1858, three years after Mr. Wicksteed's works had been established, the river Soar had become changed from a most foul and pestilential stream into a comparatively pure river; for before the sewage was purified by Mr. Wicksteed's (lime) process the water of the river was black with decomposition, all the fish and aquatic plants had been killed, and persons exposed to its influence were constantly ill. At the Belgrave Mill, which is just below the point where the sewage enters the river, the foulness of the stream was such that in the summer time the water of the mill-dam appeared to boil with putrefaction, and the stench was intolerable. So large, indeed, was the quantity of sulphuretted hydrogen evolved from the water, that the silver in the men's pockets turned black in a few hours, and, as might be expected, those who worked at the mill were constantly affected with diarrhœa, and rapidly fell off in health. One man only, out of thirty, in eighteen years, had been able to withstand the effects of the effluvium, and he it was who gave us an account of the matter. But soon after the lime process had been adopted, the river presented an entirely different appearance, for aquatic plants had begun to flourish, the fish had returned, the black mud had ceased to accumulate, and the mill-dam was no longer offensive. All along the stream the people spoke of the change with satisfaction, for the process had evidently fulfilled the requirements of the local Act of Parliament, which demands that the sewage water discharged into the river from the works shall not occasion a nuisance, or be injurious to the health of those who live or are employed upon the banks of the stream." Dr. Letheby goes on to say:—"At first the patentees of this process were so sanguine of commercial success, and entertained such extravagant opinions of the fertilizing power of the dried sewage precipitate, which they called 'sewage guano,' that great and unnecessary expense was encountered in the construction of the works at Tottenham and Leicester. They were built, in fact, with a view to commercial profit rather than for sanitary purposes; and, therefore, as soon as it was found, from experience, that the manufactured product had little or no agricultural value, and that the undertaking was unprofitable, the works were abandoned by the patentees and transferred to the local authorities. In the case of Tottenham, the machinery and plant, erected at great cost by Mr. Higgs, was purchased at an almost nominal price by the Local Board, who could, therefore, well have afforded to

use their property for sanitary purposes; but instead of this, although ample proof had been afforded of their sanitary capabilities (as witnessed by the testimonial of the Board to Mr. Higgs in the month of February, 1857), yet they were so neglected and improperly managed as to have become at last a mere pretence of the objects for which they were designed and employed. The contrast, indeed, between the condition of things in 1857, as described in the testimonial of the Board, and subsequently, was most marked; for at that time—to use the language of the testimonial—the supernatant water was discharged in a comparatively pure state into the river, so that the Board by these means were able satisfactorily to sewer and drain their populous district, and dispose of the sewage without annoyance to any one. Almost as soon, however, as the works had passed into the hands of the local authority, the process was so imperfectly conducted that the Trustees of the River Lea were obliged to commence legal proceedings, on account of the pollution of the river and the nuisance created by the discharge of foul, undefecated sewage from the works, and this at last became so serious that an injunction was obtained to prohibit the offensive practice of the Board."

Dr. Letheby then states that at Leicester also the process had recently been seriously neglected, and that at the time of a visit which he had paid to the works *the estimated quantity of lime necessary was not being used*, and the river was fast returning to the unwholesome condition in which it was before Mr. Wicksteed established his works. The annual cost of conducting the works being about £1,400, and the sale of the manure amounting only to £400, the loss had led to greater and greater neglect in the conduct of the works, and, as Dr. Letheby adds, "It is not unlikely that the foul condition of the river may be wrongly attributed to a failure of the lime process *per se*, rather than to the carelessness and false economy of those who have had the management of it."

The precipitation of sewage by lime, however, has been generally regarded by chemists as satisfactory, whenever a sufficiency of lime for the purpose has been employed. Dr. Hofmann, Mr. Witt, Dr. Clark, Dr. Crace Calvert, Mr. Versmann, Dr. Frankland, Dr. Odling, Dr. Angus Smith, Mr. Aiken, Dr. Alfred S. Taylor, Dr. Normandy, and Dr. Miller have all testified to its efficiency when fairly used; and wherever it has failed, the failure, as Dr. Letheby says, is entirely due to the carelessness and parsimony of those who have hitherto had the management of the process. Lime is one of the principal precipitating ingredients of both the phosphate and sulphate of alumina systems.

At the commencement of my paper, I suggested that the civilized being preferred taking the chance of poisoning his neighbor who lives below him on the river, to having his own senses of sight, or smell, or his sentiment, outraged; and I might with equal truth have added that the philanthropy of Local Boards and other parish authorities begins and ends at home. A measure which would, for the benefit of other communities, tax the rate-payers who elect them, can never find favor with such bodies, and amongst the evils of the water carriage is the facility which it gives for transferring the whole of one's own nastiness to the dwellings of one's neighbors. Even that great and good man, Dr. Johnson, could not resist the temptation of throwing the snails he found in his own garden into the garden adjoining, and it is improbable that any place in the kingdom will be found sufficiently unselfish to tax itself for the sake of the health and comfort of the next parish. Injunction and compulsion are the only remedies available.

In such matters, however, the probable influence of parsimony on the success of a process ought not to be neglected, and it is among the advantages of the process I am proceeding to describe to you, that the materials employed are not only the cheapest available for the purpose, but for the particular object to which I apply them no saving is effected by scrimping their use.

We owe the lime process to a treatment for softening and purifying water, patented by Dr. Clark, in 1841. He showed that carbonate of lime being to some considerable extent soluble in solution of carbonic acid gas, and scarcely so in pure water, it was only necessary to add to water thus impregnated a sufficiency of quick-lime, to combine with the free carbonic acid gas, in order to precipitate both the dissolved carbonate of lime and that which is formed by the combination of the quick-lime added and such carbonic acid. It was also found, in the application of this process, that the precipitate thus produced removed from the water a notable quantity of dissolved or-

ganic matter, as well as impurities held in suspension, and hence its great value as a precipitant of sewage. Now, a much smaller amount of lime than is sufficient to throw out of solution all the carbonate of lime present will suffice to produce clarification after standing. There are phosphoric acid and various fatty acids, besides carbonic acid, present in the sewage water, which will produce precipitates with lime; and, until the carbonic acid is saturated, each quantum of lime added will produce a double quantity of lime in the deposit, by throwing out, as has been said, not only the carbonate of lime in solution, but also the introduced lime, by its combination with the carbonic acid, which up to the period of this addition held the carbonate of lime in solution as a bicarbonate. Consequently, if the mineral deposit thrown down by the lime has any commercial value—and I hope to show you that, in the minds of those best capable of judging, it has—there is an economy in not being too niggardly in its use.

Another substance which has a recognized purifying and decolorizing action, and which is at the same time generally available, and of nominal cost, is clay. Clay has been used for defecating sewage, both in its ordinary conditions and partially dissolved in sulphuric acid. In the A B C process, out of 2,581 parts by weight, of precipitating compound, it is specified that 25 parts shall be burned clay, 1,900 parts ordinary clay, and 600 parts of alum, of which alumina—an important ingredient of clay—forms part. Again, in the sulphate of alumina process, for every 100,000 gallons of sewage, Dr. Anderson used, according to Dr. Letheby, 9½ cwt. of sulphated material, compounded in the proportion of one part of common sulphuric acid to two parts of ordinary clay, mixed with its own bulk of water; and, in some form or other, clay is an ingredient specified in many other sewage processes. In fact it was a well-recognized fact that alumina and oxide of iron, even in the condition in which they exist in common earth, have the power of absorbing noxious gases, fixing soluble organic matters, and of otherwise purifying sewage.

In lime and clay, then, we have these two substances readily obtainable everywhere—the one at little cost and the other at a nominal price—and well calculated for precipitating and defecating sewage. Moreover, those substances react on each other, and thereby increase the effect which each separately is capable of producing. Supposing we have finely divided clay suspended in pure water, the addition of lime will cause the particles of clay instantly to collect and precipitate. There is, in fact, considerable affinity between lime and clay.

It so happens that these ingredients, carbonate of lime (the substance precipitated on the addition of lime to ordinary sewage water) and clay, are the chief components of those limestones which yield on calcination hydraulic limes and hydraulic cements. This discovery was first made by Smeaton, the celebrated engineer, who says, "I have never found any limestone containing clay in a considerable quantity but what was good for water building." Subsequently, Vicat determined the proportions of clay which it was necessary limestones should contain, in order to yield limes possessing in greater or less degree the property of setting in water. He found that limestones containing from 8 to 12 per cent. of clay yielded, on calcination, limes *feebly* hydraulic; that limestones containing from 15 to 18 per cent. yielded hydraulic limes; and those containing from 20 to 25 per cent. of clay yielded *eminently* hydraulic limes. Acting on these principles, Vicat established a factory at Meudon, near Paris, at which artificial limes are made by calcining mixtures of chalk (carbonate of lime) and clay in the proportions necessary to give the required results. In this country also, and abroad, the so-called Portland cement has been made by calcining at a high temperature 75 per cent. of chalk (or carbonate of lime ground to powder when chalk is not available) intimately mixed with 25 per cent. of clay. The process commences by triturating together in a wash mill chalk and clay in those proportions with a large quantity of water. From the chalk mill there is an overflow by which the water, which is constantly running into the wash mill, may pass off, carrying with it some of the chalk and clay in suspension. The milky fluid thus produced is allowed to run into large tanks or is pumped into them, the coarser particles being detained in the channels leading to the tanks by catch pits, or some other means. When the tanks are full, the solid matters are allowed to subside, the top water is drained off as far as possible, and the operation of running the mixture into the tanks is again commenced. As the mat-

ters in suspension do not very readily settle, the process of filling the tanks with the mixture is slow and tedious; owing, also, to the greater fineness of the division of the clay than can be produced by reducing chalk to a powder, there is a considerable tendency to separation between the chalk and the impalpable particles of clay, which is rectified as far as may be by subsequent admixture of the compounds, either in the process of removal for drying, or after the mixture has been burned to cement and ground to powder.

It will be readily seen that there must be a great similarity between the compound thus produced and that which results from introducing quick-lime and clay, in the proper proportions, for cement or hydraulic lime, into a drain at some distance from the settling tanks, or into suitable mixing vessels where the ingredients can be thoroughly incorporated with the sewage water and with each other.

The chief points of difference, which are entirely in favor of the sewage process, are :—

1st. The more intimate mixture which can be brought out in the sewage water, owing to the impalpable nature of the precipitate of carbonate of lime which takes place on the addition of the lime.

2d. The more rapid settlement of the sewage precipitate than the mixture of chalk and clay.

3d. The amount of organic matters which is carried down from the sewage with the carbonate of lime and clay, and which will serve for the fuel to burn the mixture to lime or cement.

The amount of fuel, indeed, which the slush will afford is so large, that in the absence of any better mode of getting rid of the nuisance, and in consequence of the loss which results from attempting to deal with it as a manure, it has been proposed to destroy it by burning it.

Mr. Thomas Hawksley, President of the Institute of Civil Engineers, for instance, gave in evidence a week or two since, before the Committee of the House of Commons on the Birmingham Sewerage Bill, the opinion that "it was practicable to burn the sludge, which contained a great deal of combustible matter," and Mr. F. J. Bramwell, C. E., also gave evidence that "the sludge deposited at Saltley contains about 15 per cent. of solid matter, and of that 40 per cent. is combustible, and therefore could be used as fuel." Professor Abel, one of the members of the Council of this Society, who has for many years given great attention to the question of limes and cements, after witnessing one of the earliest experiments, gave the points we have been considering careful attention, and arrived at the conclusion that the gain in lime and other mineral matters derived from the sewage water, the collection from the sewage of combustible matter required for the burning of the deposit into cement, and the thorough incorporation of the cement-producing materials, must combine to render the production of cement, through the agency of this method of sewage treatment, a profitable business in large towns.

After the mixture of the ingredients has been made, and the top water drained off, the subsequent operations are similar, whether the process is that ordinarily employed for making cement, or the one now proposed. In each case the mixture has to be dried, and this operation may be performed most readily on tiled floors with heated flues beneath them, such as are used in the potteries for drying clay.

It might be supposed that the process of drying the sewage matters which are precipitated with the lime and clay would be a very disagreeable one, but it is not so. I here exhibit to you some of the deposit in question, a portion of which is also undergoing the drying process on the table, and you will find them quite inoffensive. Even after four months, we have found that the deposit is still without smell; and though the time of the year at which the experiment has been made may have been very favorable, yet it can hardly be doubted that, even in the heat of summer, the deposit would remain free from smell for some days, and it could be treated, if necessary, day by day. In order, however, that on so important a point as this you may have the fullest evidence, I will again refer you to that recently given before the Committee of the House on the Birmingham Sewerage Bill on this question. Dr. Voelcker, consulting chemist of the Royal Agricultural Society, stated: "Experiments as to making cements from detritus according to General Scott's plan, are by no means a nuisance." "The suspended matters in sewage are always very offensive, and that is the reason why populations are so anxious to get rid of them. If they were allowed to accumulate, they would, of course, get into a state of

putrefaction, but you can use chemical action upon them, and even when they accumulate for a certain time—by General Scott's plan, especially—they can be kept free from putrefaction." Dr. Frankland, Professor of Chemistry at the College of Chemistry, and one of the Rivers Pollution Commissioners, says of the lime and clay process of precipitation: "The deposit, also, would be absolutely inodorous;" and Mr. F. J. Bramwell, C. E., states: "No injury would be likely to arise in the way of nuisance from dealing with the sludge in the manner proposed."

Having cleared away, as I trust, any doubts you may have as to the inoffensiveness of the process of drying, I proceed to the last stage of the manufacture, in which also some very unfounded suspicions may naturally exist in the minds of those who have not had the advantage of that technical education concerning which so much is said and so little done. Before, however, taking up the question of calcination of the dried deposit, I ought to call your attention to the fact that in the dry condition the compound has by no means a disagreeable odor. I can hardly say of it, as it is said of the Chinese "tafo," a somewhat similar material, that it has the smell of violets, but I am quite certain that no one would have the least suspicion of its origin, either from its appearance or odor. Some visitors to the works, indeed, have pronounced that it has the smell of new bread; but I leave it to you to judge of this for yourselves. I have provided a small store of the compound for distribution. The compound may be either completely dried on the flues, or it may, when it has reached a certain consistency, be made into bricks and allowed to dry in the air, as has been done with the specimens which I have passed round for your examination. In this dry condition, the deposit can be preserved for any time without creating the slightest nuisance, and it is hardly necessary to point out that, from the commercial point of view, it is of no small consequence that the raw material should be inexpensive, especially when it is possible that the finished manufacture may remain on hand for some time. To give an example of what I mean, I may explain to you that the deposit which they are now obtaining from the Leeds sewage is not being disposed of as it is produced, and, as I understand, it is the intention of the Native Guano Company to preserve it for twelve months, in order to improve its quality by fermentation. Now, the value of the materials required for precipitating 252,352 gallons is, according to the Rivers Pollution Commissioners, £1 18s. 5d., without assigning any value at all to the 1,156 lbs. of clay used, and the 7 lbs. of blood, whereas the value of materials, including the clay, used in the cement process for the same quantity of water would not exceed, in the generality of cases, 4s. 6d., and could not in any place in the country exceed 7s. 6d.

On these data, a year's supply of chemicals at a place like Leeds would, in the A B C process, which is now being tried there on a portion of the sewage, cost upwards of £30,000 per annum. The supply of materials for the same period for the cement process would not exceed £6,000 or £7,000. I say nothing about the value of the manure resulting from the A B C process, or the cement produced by mine, the point to which I desire to draw your attention here being simply the amount of capital required for the purchase of the materials in the two cases.

For the phosphate of alumina process the cost of the chemicals would exceed £45,000 per annum in such a case as Leeds, and for the sulphate of alumina system would considerably exceed £20,000 per annum.

To return, however, to the question of calcination. It has been constantly objected, by persons unacquainted with the elements of chemistry, that cement derived from such a source must have some of the objectionable qualities of sewage, and must therefore be unsuited for plastering the walls of our houses; but people do not consider that to employ the material as manure for the vegetables they eat is, in itself, far more repugnant to our natural feelings. I am told that when some cement, prepared from sewage, was a few days since exhibited to a party of gentlemen, some of them could not be induced to touch it, though they were informed that the material had been subjected to calcination at a high temperature, and that every objectionable element which the sewage deposit may have once contained had been resolved into perfectly harmless inorganic compounds. I wonder if the same gentlemen had been informed that the vegetables before them at their dinner-table were from Mr. Morgan's sewage-farm at Barking, they would have

turned from them with equal disgust? And yet, if the fears of some writers on the subject are well grounded, disgust in the latter case would not be without some reason. Passing by the question whether watercresses grown in sewage water produce diarrhœa, or feeding cows on sewage grass causes their milk to turn sour more quickly, or whether such feeding introduces parasitic disease into our beef and mutton, it must be admitted that organic life is materially modified by the food it lives upon; but no one with the slightest pretention to scientific knowledge would assert that a single particle of a deleterious nature can be left in sewage-made cement after calcination. On the other hand, many will be found who will contend that the practice of irrigation with sewage from which the fecal matters are not removed is liable to cause diseases of a serious nature, as well as a dreadful nuisance, and that the only certain way of preventing the propagation of the seeds of infection which may reside in the slush is to destroy them by fire.

I think I may venture to assert, in short, that the strongest advocates of irrigation or of filtration are in favor of the removal of the slush as a preliminary measure; that most of the authorities prefer that this should be done by precipitation; that few of the chemists who have studied the question of manures will admit that sufficient fertilizing ingredients can be found in the slush to pay for the expense of collecting and drying the material; that the plan of burning the slush commends itself to most of the chemists and engineers who have considered the various modes of getting rid of its nuisances; and that the combination of the destruction of the slush by fire with the preparation of cement, for which the excellent precipitants and deodorizers, lime and clay, are precisely suited, offers the best prospect of turning an otherwise waste, useless, and noxious product into a marketable substance.

That I am not overstraining my case will be evident from the following testimony, not, be it remembered, solicited by me, but given in evidence before the Parliamentary Committee which has just concluded its labors in the matter of the Birmingham Sewerage Bill.

Dr. William Odling, Professor of Chemistry at the Royal Institution, said: "I don't think there is any commercial value in the matter to be extracted at Dunton, except in its use as Portland cement." And Dr. Edward Frankland, F.R.S., one of the Commissioners for Inquiry into the Pollution of Rivers, said: "There are various modes of purifying the sewage, and I should prefer to deal with the sludge according to General Scott's system, namely, turning it into cement." "The process of treatment at Dunton, which I would recommend, is to mix lime and clay with the sewage shortly before it reaches the tank. That would produce a complete deposit in the tanks, and would deodorize the sewage, which would flow on to the land without any smell arising from it; and the deposit also would be absolutely inodorous. That deposit would be dried and converted into Portland cement."

But it may be objected, these are the theoretical ideas of men of science which practice would not justify. I therefore refer with satisfaction to the evidence to the same effect given by an eminent engineer. Mr. F. J. Bramwell, C. E., said General Scott's plan of "converting the sludge into cement is very satisfactory, and from what I have seen of the cement I have the highest opinion of it."

I have one more opinion to give you, and this, for obvious reasons, I have reserved for the last. It is given in the evidence of the distinguished engineer who occupies the chair this evening. If it is not what he really stated, he must blame the reporters, but the Birmingham papers give him credit for having asserted that "by adopting General Scott's process it (the slush) could be converted into a very useful and valuable cement."

Let me say, in conclusion, that at the time when I requested Mr. Hawksley to take the chair this evening, I neither knew the opinion he had expressed nor the view he took of the matter. I believe, indeed, that his evidence must have been given and my note of invitation been written on the same day.

THE Clinton "Herald" announces that Colonel Milo Smith has closed up transactions and passed the money over to the amount of nearly $40,000, in securing the necessary grounds and the right of way for the Chicago, Burlington and Quincy, the Chicago, Clinton and Dubuque, and the Chicago, Omaha and St. Joe railroads, in that city.

THE INFLUENCE OF GAS AND WATER PIPES IN DETERMINING THE DIRECTION OF A DISCHARGE OF LIGHTNING.

By Mr. HENRY WILDE.

From "The Mechanics' Magazine."

As very considerable damage has been done lately by lightning, the following paper from the proceedings of the Literary and Philosophical Society of Manchester may prove of interest. Although the invention of the lightning conductor is one of the noblest applications of science to the wants of man, and its utility has been established in all parts of the world by the experience of more than a century, yet, a sufficient number of instances are recorded of damage done by lightning to buildings armed with conductors to produce, in the minds of some, an impression that the protective influence of lightning conductors is of but questionable value.

The destruction by fire of the beautiful church at Crumpsall during a thunder-storm on the morning of the 4th of January last, has induced me to bring before the Society, with a view to their being known as widely as possible, some facts connected with the electric discharge which have guided me for some years in the recommendation of means by which disasters of this kind may be averted.

For the proper consideration of this subject it is necessary to make a distinction between the mechanical damage, which is the direct effect of the lightning stroke, and the damage caused indirectly by the firing of inflammable materials which happen to be in the line of discharge.

Instances of mechanical injury to buildings, not provided with conductors, are still sufficiently numerous to illustrate the terrific force of the lightning stroke, and at the same time the ignorance and indifference which prevail in some quarters with respect to the means of averting such disasters; for wherever lofty buildings are furnished with conductors from the summit to the base, and thence into the earth, damage of the mechanical kind is now happily unknown.

Even in those cases where lightning conductors have not extended continuously through the whole height of a building, or where the lower extremity of the conductor has, from any cause, terminated abruptly at the base of the building, the severity of the stroke has been greatly mitigated, the damage being limited, in many cases, to the loosening ot a few stones or bricks.

The ever-extending introduction of gas and water pipes into the interior of buildings armed with lightning conductors has, however, greatly altered the character of the protection which they formerly afforded, and the conviction has been long forced upon me, that, while buildings so armed are effectually protected from injury of the mechanical kind, they are more subject to damage by fire.

The proximity of lightning conductors to gas and water mains, as an element of danger, has not yet, so far as I know, engaged the attention of electricians, and it was first brought under my notice at Oldham in 1861, by witnessing the effects of a lightning discharge from the end of a length of iron wire rope, which had been fixed near to the top of a tall factory chimney, for the purpose of supporting a long length of telegraph wire. The chimney was provided with a copper lightning conductor terminating in the ground in the usual manner. In close proximity to the conductor, and parallel with it, the wire rope descended, from near the top of the chimney, for a distance of 100 ft., and was finally secured to an iron bolt inserted in the chimney about 10 ft. from the ground. During a thunder-storm which occurred soon after the telegraph wire was fixed, the lightning descended the wire rope, and, instead of discharging itself upon the neighboring lightning conductor, darted through the air for a distance of 16 ft., to a gas meter in the cellar of an adjoining cotton warehouse, where it fused the lead pipe connections and ignited the gas. That the discharge had really passed between the end of the wire rope and the lead pipe connections, was abundantly evident from the marks made on the chimney by the fusion and volatilization of the end of the wire rope, and by the fusion of the lead pipe. As the accident occurred in the daytime, the fire was soon detected and promptly extinguished.

Another and equally instructive instance of the inductive influence of gas pipes in determining the direction of the lightning discharge occurred in the summer of 1863,

at St. Paul's Church, Kersal Moor, during divine service. To the outside of the spire and tower of this church a copper lightning conductor was fixed, the lower extremity of which was extended under the soil for a distance of about 20 ft. The lightning descended this conductor, but, instead of passing into the earth by the path provided for it, struck through the side of the tower to a small gas pipe fixed to the inner wall. The point at which the lightning left the conductor was about 5 ft. above the level of the ground, and the thickness of the wall pierced was about 4 ft.; but beyond the fracture of one of the outer stones of the wall, and the shattering of the plaster near the gas pipe, the building sustained no injury.

That the direction of the electric discharge had, in this case, been determined by the gas pipes which passed under the floor of the church, was evident from the fact that the watches of several members of the congregation who were seated in the vicinity of the gas mains were so strongly magnetized as to be rendered unserviceable.

The church at Crumpsall is about a mile distant from that at Kersal Moor, and the ignition of the gas by lightning, which undoubtedly caused its destruction, is not so distinctly traceable as it is in other cases which have come under my observation, because the evidences of the passage of the electric discharge have been obliterated by the fire. From information, however, communicated to me by the clerk in charge of the building as to the arrangement of the gas pipes, the most probable course of the electric discharge was ultimately found.

The church is provided with a copper lightning conductor, which descends outside the spire and tower as far as the level of the roof. The conductor then enters a large iron down-spout, and from thence is carried into the same drain as that in which the spout discharges itself. Immediately under the roof of the nave, and against the wall, an iron line of gas pipe extended parallel with the horizontal lead gutter which conveyed the water from the roof to the iron spout in which the conductor was enclosed. This line of gas-piping, though not in use for some time previous to the fire, was in contact with the pipes connected with the meter in the vestry, where the fire originated, and was not more than 3 ft. distant from the lead gutter on the roof. As no indications of the electric discharge having taken place through the masonry were found, as in the case of the church at Kersal Moor, it seems highly probable that the lightning left the conductor at the point where the latter entered the iron spout, and by traversing the space between the leaden gutter and the line of gas-piping in the roof, found a more easy path to the earth by the gas mains than was provided for it in the drain.

In my experiments on the electrical condition of the terrestrial globe I have already directed attention to the powerful influence which lines of metal extended in contact with moist ground, exercise in promoting the discharge of electric currents of comparatively low tension into the earth's substance, and also that the amount of the discharge from an electro-motor into the earth increases conjointly with the tension of the current and the length of the conductor extended in contact with the earth. It is not, therefore, surprising that atmospheric electricity, of a tension sufficient to strike through a stratum of air several hundred yards thick, should find an easier path to the earth by leaping from a lightning conductor through a few feet of air or stone to a great system of gas or water mains, extending in large towns for miles, than by the short line of metal extended in the ground which forms the usual termination of a lightning conductor.

It deserves to be noticed that in the cases of lightning discharge which I have cited, the lightning conductors acted efficiently in protecting the buildings from damage of a mechanical nature—the trifling injury to the church tower at Kersal Moor being directly attributable to the presence of the gas pipe in proximity to the conductor. Nor would there have been any danger from fire by the ignition of the gas if all the pipes used in the interior of the buildings had been made of iron or brass instead of lead; for all the cases of the ignition of gas by lightning which have come under my observation have been brought about by the fusion of lead pipes in the line of discharge. The substitution of brass and iron wherever lead is used in the construction of gas apparatus would, however, be attended with great inconvenience and expense, and, moreover, would not avert other dangers incident to the disruptive discharge from the conductor to the gas and water pipes within a building. I have therefore recommended that in all cases where lightning conductors are attached to buildings, fitted up with gas and water pipes, the lower extremity of

the lightning conductor should be bound in good metallic contact with one or other of such pipes outside the building. By attending to this precaution the disruptive discharge between the lightning conductor and the gas and water pipes is prevented, and the fusible metal pipes in the interior of the building are placed out of the influence of the lightning discharge

Objections have been raised by some corporations to the establishment of metallic connection between lightning conductors and gas mains, on the ground that damage might arise from ignition and explosion. These objections are most irrational, as gas will not ignite and explode unless mixed with atmospheric air, and the passage of lightning along continuous metallic conductors will not ignite gas even when mixed with air. Moreover, in every case of the ignition of gas by lightning, the discharge is actually transmitted along the mains, such objections notwithstanding. A grave responsibility therefore rests upon those who, after introducing a source of danger into a building, raise obstacles to the adoption of measures for averting this danger.

REPORTS OF ENGINEERS' SOCIETIES.

THE NEW YORK SOCIETY OF PRACTICAL ENGINEERING.—At the May meeting of the New York Society of Practical Engineering, the subjects discussed were type-composing machines and the steam-engine indicator. The paper upon the first-named subject was by Eugene Le Hardy de Beaulieu, the latter from Mr. Henry L. Breyoort. Mr. Beaulieu advocated the Delcambre machine, a French invention, in which the type are taken from the type-boxes, along inclined guides, by the action of gravity, to the "stick." The "justification" is, as usual in machines of this kind, done by hand. The enormous sums paid annually by the daily newspapers in New York for composition—ranging from $100,000 to $200,000 each—are sufficient to show the great importance of any machine which will effect a material saving in this department.

Mr. Brevoort characterized the indicator as a device by which the expert is enabled to gain an insight into the working of machinery, and by its aid apply both power and machinery to the best advantage. The utility of the indicator devised by Watt and applied to low-pressure engines was mentioned, together with the advantages from the first derived from its use. Its utter impracticability for the rates of speed now employed, sometimes amounting to 1,000 ft. per minute, rendered some other instrument for the purpose necessary. This is found in the Richards indicator, in which the motion of the piston and the length of the spring are both diminished by one-quarter. The non-user of the indicator frequently loses more through waste of coal arising from ignorance of the actual performance of the steam in the engine, than the cost of the indicator and the time and labor required in its frequent use. The use of the instrument is of the greatest value in adjusting valves with the requisite delicacy, since an engine may not unfrequently be in apparently the best working order when cold, yet under the influence of heat show decided defects of adjustment. Until a recent time, the instruments of foreign make have proved of better construction than those made in America. Manufacturers in this country have of late made decided improvements in the attachment of the spring, giving greater reliability under extreme pressure. In the former construction, the circular brass ends of the springs were applied in a slot cast all the way round, and after adjustment had been made they were fastened by pouring in melted white metal. Under considerable pressure one coil of the spring frequently rested upon another, injuring the action of the spring very much. The remedy for this is found in making two horizontal slots in the brass ends of the springs, and by means of them adjusting the spring so that it is supported at only two points, thus securing a uniform action of the spring under all pressures. Frequent tests of indicator springs are necessary even after they have been approved in practical trials, and these tests should be applied at the temperatures to which the springs are habitually subjected when testing engines.

The usual indicator piston is a cylinder closed at the top and open below. A recent modification in them is to bevel the lower edge from the inside outward, taking care not to make the thin edge so weak as to be unduly expanded on the admission of steam to the interior. This has been found to work very well. A suggested improvement is to prolong the tube of the piston above as well as below, in order to guard against a leakage from without inwards under a vacuum, as well as to resist higher pressures than those for which provision is commonly made. This form of piston in section would resemble an H. The piston-rod would be fastened by a ball-and-socket joint at the centre, and the usual shallow grooves semi-circular in section turned upon the outside. The most convenient and efficient modes of taking cards, the value of reducing-wheels, and various adjuncts to the indicator which have been suggested, were taken up and considered by the writer with considerable minuteness.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The fifth annual meeting of this Society was held at Chicago, June 7th, and Mr. E. S. Chesbrough was elected president. In the absence of any extended report of the proceedings, we can only give a few items, with the titles of the papers read upon different subjects:

"Early History of Railways and the Origin of Gauge," by J. D. Steele, of Coatesville, Pa.

Mr. Stephen Chester, of New York, read a paper on "Electro-Science as a Part of the Education of Civil Engineers."

A paper was read upon "Engineering," written by W. Milnor Roberts.

Mr. A. P. Boller read a paper on the "Fellowship Fund" of the Society.

Mr. Arthur, of Philadelphia, read a paper on "The Automatic Cut-off."

Mr. E. S. Chesbrough followed with an interesting paper on the "Detroit River Tunnel." The paper narrated in some detail the preliminary survey to obtain the most feasible line for the tunnel. The river at the point runs nearly east, and is half a mile wide. The length of the portion of the tunnel under the river is 3,000 ft. There are to be 20 ft. of earth between the masonry and the river bed. The tunnel was to be made circular, and of sufficient diameter to allow the largest Pullman car to pass through. By having five or six working forces, the tunnel could be prosecuted so vigorously as to have it completed in less time than a year. The entire cost of the work was estimated at $2,650,000. The rate of progress thus far had been less than the contemplated rate. Mr. Chesbrough described the devices which he made use of to protect the men from sudden danger from any cause. Mr. Chesbrough said the auger used to test the ground was of wood, and that the earth which stuck to the point of the auger always indicated the nature of the earth where the boring ceased.

The next paper read was on "Strains of Bridges," by T. C. Clarke, of the Phœnixville Bridge Works.

This was followed by a paper by James B. Francis, of Lowell, Mass., on "Experiments in the Deflection of Continuous Beams Supported at Equidistant Points."

Mr. F. Collingwood read an interesting paper entitled "Further Notes on the East River Bridge." The paper detailed the method employed in sinking the caissons, the devices necessary to enable the workmen to work within them safely and conveniently, and the effects of the compressed air upon the men, resulting in some instances in injury, and in one or two in death.

Mr. Walter Katte, of St. Louis, read an account of the "Method of Construction of the Illinois and St. Louis Bridge." The paper was accompanied by a large diagram, which showed to the eye the machinery in process of supporting the partially finished arches; and Mr. Katte explained how the engineers in charge proposed to put in the last link, or keystone of each arch.

The next paper was written by R. G. Hatfield, the subject being "Building Materials." It was read by Mr. Charles Macdonald.

The paper written by Edmund Yardley on "Cements," was read by Mr. A. P. Boller.

A paper on "Closing Breaks in Dams under Difficulties" was read by O. B. Whitford, of Oswego, New York.

The last paper read was written by Henry L. Lubers, of East St. Louis, on the "Manufacture of Coke from Illinois Coal, and the Process Employed in Purifying Slack Coal." It was read by Stephen Chester, in the absence of the author.

The last paper presented to the Association, that of Mr. Eichbaum, on the "Selection of Stone for Masonry," was not read, but was ordered printed with the Transactions.

During the meeting a discussion was held on the depth to which caissons could be sunk without endangering the lives of the workmen employed within them.

Mr. Steel said it had been a serious question in New York whether the caissons in the East River could be sunk the requisite depth, 105 ft., without endangering the more delicate workmen, from the weight of the compressed air.

Mr. Katte said the greatest pressure in the caissons used in constructing the piers of the St. Louis bridge was about 50 lbs., and he did not know of a single case of injury to the workmen caused by the pressure.

Mr. Collingwood said if it were taken for granted that a man could labor 12 hours continuously in the ordinary air, then, with a pressure of two atmospheres, he could labor about half that time; in a pressure of three atmospheres about one-third the time, and in a pressure of four atmospheres about one-fourth that time. If the men had a proper chance to rest, there was no danger. The great difficulty was the change back again to the external air after working in the caisson.

Mr. McAlpine thought the effect of the compressed air was like that of a stimulant, and the danger was when the stimulant was withdrawn. The compressed air had something of the effect of laughing-gas. By a gradual application of the pressure he had known workmen to work under a weight of five atmospheres, without the slightest injury.

We hope hereafter to have the pleasure of giving our readers the different papers read, *in extenso*, or at least such abstracts of them as the different writers may consider it safe for the profession to see.

IRON AND STEEL NOTES.

REMARKABLE OCCURRENCE OF SPHEROIDAL IRON ORE.—We bore up to the island of Owen in two days. This little island is only separated from New Caledonia by a narrow and deep channel, known as the Woodin Channel. I went on shore with my baggage, instruments, and provisions, landing on a flat beach forming the head of a large bay, round which is situated the village of Oura, the residence of the island chief. The island did not offer an agreeable residence. Its shores are high, rocky, and barren, with perpendicular cliffs. The small deltas at the embouchure of the streams form the only valleys—on these the natives have their plantations. The interior of the country displays one very remarkable particular; it is nearly altogether composed of iron ore. This exists in such abundance that it is destined to be a source of future profit. The iron occurs in spheroids, like very large bullets, which are heaped together pell mell. They form occasional plateaux many thousand metres square. These immense heaps are occasionally degraded by the lengthened action of rains, and are left as gigantic cones of iron. Such a cone is that of Mamié on the northeast of the island. On the edge of the platforms we frequently noticed that the blocks of iron had been collected by manual labor and arranged in lines. The natives explained this to me by stating that in their old wars the vanquished, flying from their enemies, abandoned the plain and took refuge in the hills, which they thus fortified. From these defences they rolled down iron balls on their assailants. Few plants subsist on this metallic soil. About the middle of the day the solar heat retained by the iron is so excessive, that during several hours

it is impossible to handle the blocks. Notwithstanding the thick soles of our boots our feet suffered from the intolerable heat. One other consequence of the peculiar nature of the soil is that the water of some streams flowing over the iron is elevated to an extraordinary temperature. The inhabitants of the island of Oura, by reason of the scarcity of its resources, are obliged to resort to the mainland to establish their plantations. The immense flats of coral to the south afford turtle, shell fish, and fish in abundance. The people also obtain on the sands the eggs of seafowl and turtle. I have often accompanied them on these expeditions—it is on such occasions that one best learns to appreciate their intelligence, strength and skill.

IRON AND STEEL EXPORTS.—The exports of iron and steel from the United Kingdom promise to attain a very considerable aggregate this year, although the increasing dearness of both iron and steel naturally exercises a chilling and deterrent effect upon foreign and colonial consumption. The shipments of rails in May showed a very great falling off as compared with May, 1871, the American demand having at last given way; but still the aggregate exports of iron and steel in May, amounted to 357,482 tons, as compared with 350,786 tons in May, 1871, and 317,725 tons in May, 1870, while for the first five months of this year the complete shipments came out thus:

Month.	1870.	1871.	1872.
January.....Tons	172,749	111,784	200,095
February.....	178,554	137,397	215,100
March	223,412	242,166	248,512
April.....	270,079	284,190	334,360
May.....	317,725	350,786	357,482
Total	1,162,519	1,126,·23	1,355,549

The shipments, it will be observed, show only a feeble progress in May as compared with May, 1871; but the wonder is that they come so well out of the comparison, since the value of the 357,482 tons exported in May was £3,460,493, while the 350,786 tons exported in May, 1871, were priced at only £2,782,973. As regards the value of the steel and iron exported, this year seems certain to attain a marked pre-eminence, the figures for the first five months of 1872 being in excess of the corresponding totals of the corresponding periods in 1858, 1859, 1860, 1861, and 1862. This will be seen on a glance at the annexed table:

VALUE OF IRON AND STEEL EXPORTED.

Year.	Total.	Year.	Totals.
1856.... ...£12,966,109		1865 .. ....£13,471,359	
1857..... 13,603,337		1866..... 14,842,417	
1858..... 11,197,072		1867 15,050,391	
1859 .. 12,314,437		1868 15,036,398	
1860..... 12,154,997		1869..... 19.480,950	
1861..... 10,326,646		1870 24,038,090	
1862..... 11,365,150		1871..... 26,149,136	
1863..... 13,150,936		1872 (5 mos. 12,841,459	
1864..... 13,310,484			

The statistics of the last three years have, we believe, been kept upon a modified principle, and some descriptions of steel have been embraced of which no account was previously taken; nevertheless, there can be no doubt that the export steel and iron trades have enormously extended during the last eight or ten years, while this year's value total will be very greatly swollen by the extraordinary upward movement which has taken place in prices.—*London Mining Journal*.

RAILWAY NOTES.

THE CINCINNATI AND TERRE HAUTE RAILWAY COMPANY, organized for the purpose of constructing a railway from the cities of Cincinnati, Ohio, to Terre Haute, Indiana, and to develop the coal and mineral land of the State of Indiana, have leased over 50,000 acres of the block coal fields in Clay and Owen counties, bordering upon the line of their railway; said leases being located in the heart of the block coal seam, and comprise the best and most valuable part of the Indiana coal field, and which they now desire to develop, in conformity to the following notice:

THE CINCINNATI AND TERRE HAUTE RAILWAY COMPANY,

Desirous of enlisting the attention of manufacturers to the advantage of locating manufacturing establishments upon the line of their railway, will give to any rolling mill or blast furnace company so locating, 40 acres of ground for works, and the coal in 100 acres of Clay or Owen county, Indiana, block coal field; the ore from 100 acres of the Hardin, Pope, or Massac county, Illinois, brown hematite, or the Green county, Indiana, native ore beds, and agree to furnish them with all orders for merchant iron required for the railway's use for a period of two years.

To any railway car manufactory located upon its line, they will give 10 acres of ground required for works, the timber from 100 acres of the best oak timbered land in Owen county, and an order for 1,000 cars to commence work upon.

To any car wheel foundry or axle forge, the necessary grounds for works, and liberal orders for their products in kind.

To all other manufacturing establishments ample facilities in the locating and successful prosecuting of their works.

In execution of the above they have laid out a manufacturing town to be called "Bessemer," upon the line of their railway 40 miles from Terre Haute, and where their road crosses the Evansville and Vincennes Railroad, at a station known as "Farmers," situated 65 miles from Indianapolis, and 52 miles from Vincennes. The present town site comprises an area of 2,500 acres, in part prairie land, bordering upon Fish creek and the White river. These streams afford an unlimited supply of pure soft water suitable for manufacturing and steam purposes, their source and drainage area being distant from any mining localities or other sources of contamination that so seriously affect many manufacturing districts. The prairie land in the town is a rich alluvial deposit, cultivated for a long number of years, raising the finest corn and wheat in southern Indiana. Wells sunk 12 to 14 ft. in depth reach an unfailing supply of soft water. The hills bordering the limits of the town are high and of easy slope with broad level table lands on their summits, affording fine locations for residences, while blast furnaces that require a high level railway for the discharge of

crude material at the trundle head, can have the same without material additional expense. Fine magnesian limestone and sandstone quarries abound in the town site limits, the beds of which are level, the strata varying from 1 to 10 ft. in thickness. Hard blue limestone suitable for furnace flues can be obtained within 3 miles from the town. Good clay for brick-making is of easy access, and the locality abounds in the most densely wooded and finest timbered land in the State. The finest sandstone quarries, for grindstone uses, are contiguous to the locality, while the short distance to the block coal field affords an unfailing source of fuel for all the demands of the future manufacturing interests.

The junction of the St. Louis and Cincinnati Railway with the Cincinnati and Terre Haute Railway will be near the town site, and between it and the coal field. The Company will locate their general shops and round houses of the St. Louis and Cincinnati Railway at Bessemer, which will be made the terminus of the Middle, Terre Haute, and St. Louis divisions of the roads, and all due facilities for shipment of manufactured products are secured by the connections with the Indianapolis and Vincennes Railway and other intersecting lines, to wit: At Bloomington, Ind., with Louisville, New Albany and Chicago Railroad; at Indianapolis with all roads centring at that point; at Columbus, with the Jeffersonville, Madison, and Indianapolis Railroads; at Greensburgh, with the Indianapolis, Cincinnati, and Lafayette Railroad; at Terre Haute, with the various railroads entering at that point, to wit: two East and West, two North and South, or eight outlets in all.

Beds of native ore abound in the immediate vicinity, while various seams of coal, including the Cannel coals, are of such easy access as to warrant the prompt return of investments made in these mines.

Deeds in fee-simple of all lands required for manufacturing purposes will be made to persons or incorporated companies that desire to locate in their town. Ample facilities will be afforded parties to examine the site and the coal lands along the line of the Cincinnati and Terre Haute Railway.

Kansas Pacific Railway, 1871.

	1870.	1871.
Average length of road operated, miles	551	673
Gross earnings	$3,350,786 61	$3,342,517 83
Operating expenses	2,480,640 46	2,302,589 96
Net earnings	880,746 15	1,009,927 87
Gross earnings per mile	6,099 43	4,922 02
Operating expenses per mile	4,499 85	3,421 38
Net earnings per mile	1,599 58	1,500 64
Percentage expenses per earnings	73.79	60.5

In the total of gross earnings there is an apparent falling off of $48,268.78 in 1871; but there was no new road in course of construction during the year, and no income from transportation of construction material. The revenue from this source in 1870 amounted to $385,965.80, being the charges for material for the Denver extension. If this item is omitted from the comparative statement, the ordinary business of the road for 1871 shows an increase of $387,697.02. This increase of earnings from ordinary business is at the rate of 11 35-100 per cent.

The earnings from ordinary freight traffic were as follows:

In 1871	$1,980,289 57
In 1870	1,856,454 00
Increase	$123,035 43

Equal to 6 67-100 per cent.

The earnings from passenger service were:

In 1871	$1,285,748 09
In 1870	1,078,602 85
Increase	$207,145 24

Equal to 19 2-10 per cent.

The following were the sales of lands included in the Denver extension land grant trust (which covers 3,000,000 acres of land lying between the 300th mile post and Denver):

Acres sold	81,690 8-100
Aggregate amount of sales	$123,480 90
Average rate per acre	5 62
Bonds cancelled by trustees from sinking fund, to December 31, 1871	34,000 00
Total bills receivable (bearing interest) in hands of trustees	92,326 92

The sales of lands and lots included in the Kansas Pacific land grant trust (which covers 2,000,000 of acres of lands lying east of the 300th mile post) were as follows:

Acres sold	98,788 10-100
Town lots	50
Aggregate amount of sales	$313,340 04
Average rate per acre	3.13
Bonds cancelled by trustees from sinking fund to December 31,1871	111,000 00
Total bills receivable (bearing interest) in hands of trustees	209,653 08

The 2,000,000 acres of land embraced in this trust comprise all the unsold lands belonging to the company, east of the 300th mile post, and at the average rate per acre obtained from sales made during the past year, they will ultimately yield an aggregate of 6,260,000.

The Vanderbilt Underground Railway.—In anticipation of obtaining Gov. Hoffman's signature to the Vanderbilt Underground Railway bill, Superintendent Buckhout, of the Harlem road, has had under his direction for two or three days past, a corps of surveyors, with a view to beginning the work immediately. The road will start at the junction of Broadway and Park row, and proceed by way of the Bowery and Fourth avenue to the Grand Central Depot. A force of 3,000 laborers is ready to begin operations, and although three years are allowed by the bill for the completion of the road, Mr. Buckhout believes a much shorter time will suffice. Pending the action of the Governor, no definite plans have been adopted.

An impression prevails to some extent that when the road is in operation, the smoke rising from the locomotives will be a nuisance in the City Hall Park. On the contrary, the locomotives

will consume their own smoke and gas, and it is intimated by Superintendent Buckhout that the cars also will be of a peculiar construction, to facilitate the transfer of passengers at Fifty-sixth street.

An arrangement has been made by which the mail cars of the Harlem, Hudson River and New Haven railroads will be transported, by a continuous track, immediately into the basement of the new Post-office, and returned by another track, thus avoiding the delay of horse transportation, and enabling business men to obtain their letters an hour earlier than at present.

THE PANAMA RAILROAD.—This line is in good order, and fully equipped. From the opening of the Central Pacific and Union Pacific Railroads, the receipts declined rapidly, and in the latter part of 1870 and the beginning of 1871 they were barely sufficient to cover the working expenses, subsidy, and interest. The China trade was also diverted from the Panama Railroad to the overland route. The loss was almost entirely on the California route, and the Panama Railroad Company then made special efforts, through reduced charges, to divert shipments from sailing vessels going round Cape Horn. By means of these inducements the receipts for the first three months of 1872 were increased.

PERFORMANCE OF ENGINES.—At the recent meeting of the Master Mechanics' Association, the report on "the Comparative Cost of Operating Eight and Ten Wheel Locomotives" was read. On sixteen roads heard from, 8 and 10-wheel locomotives cost for repairs, respectively, $4.11 and $5.78; fuel, $9.53 and $11.23; stores, 85c. and $1.56; and the tons hauled in proportion to weight of engines was greatly in favor of the 8-wheel engine.

The report on "the comparative performance and cost of operation of 10-wheel engine with six drivers coupled, and 8-wheel engines with four drivers coupled,' showed that the Mogul engine (8-wheel) can be run for 33 per cent. less than the others, and they are recommended as best for freight work.

ENGINEERING STRUCTURES.

PROGRESS OF THE ST. LOUIS BRIDGE.—Even to outside observers who know little about what is, or is not, rapidity of execution in such a work, the St. Louis bridge appears to be going forward rapidly. The western abutment is all finished but the cornice (which will be left to the last). The west pier will be completed in about twenty days; the east pier in about forty days, and the east abutment in about sixty days. The manufacture of the superstructure is going on at the Keystone Works, Pittsburg, with great rapidity, as they are running night and day. The immense steel and iron bolts and "skew-backs" are all completed. The bolts are all in place in the masonry.

The superstructure will be completed about the middle of August. The upper roadway will be 54 ft. wide, including two sidewalks, each 8 ft. in width. This leaves a width of 38 ft., which will be divided into four tramways—two for street cars and light driving, and two for heavy teams. Underneath the above will be a double track railroad.

Negotiations are now on foot which will lead to the completion of the tunnel at the same time with the completion of the bridge, all of which, it is said, will be done in about a year from this time.

ALBANY BRIDGE.—The largest double track iron bridge ever built in this country was recently completed over the Hudson between East Albany and Albany. The work was commenced May 24th, 1870, and the first stone of the substructure was laid on the succeeding June 25th. The main bridge is 1,525 ft. long, and consists of seven spans over the basin, 13 ft. 3 in. each from centre to centre of piers; four fixed spans over the main channel, 185 ft. each, and a draw 274 ft. long, with two openings of 111 ft. each in the clear. The curve of the bridge over the basin is on a radius of 710 ft. The main bridge is 30 ft. above low water, and 8 ft. above high water mark, and is constructed on a vertical curve having a rise in the middle of 15 in. The whole length, with its approaches, and including an embankment crossing Van Rensselaer island, is 2,250 ft.—equal to 4,500 ft. of single track bridge. The abutments and piers are build on pile foundations, 160,000 yards of stone being used in their construction. The superstructure consists of 2,000 tons of iron, mostly wrought, its trusses being 26 ft. apart in the clear. The fabric is calculated to stand a load of 6,000 lbs. per lineal foot, besides its own weight. The entire cost was $1,000,000. It is at present used for freight trains and foot passengers.

THE DEEPEST WELL IN THE WORLD.—At about twenty miles from Berlin is situated the village of Sperenberg, noted for the deepest well that has ever been sunk. Owing to the presence of gypsum in the locality, which is at a moderate distance from the capital, it occurred to the Government authorities in charge of the mines to attempt to obtain a supply of rock salt. With this end in view the sinking of a shaft, or well 16 ft. in diameter, was commenced some five years ago, and at a depth of 280 ft. the salt was reached. The boring was continued to a further depth of 960 ft., the diameter of this bore being reduced to about 13 in. The operations were subsequently prosecuted by the aid of steam until a depth of 4,194 ft. was attained. At this point the boring was discontinued, the borer or bit being still in the salt deposit, which thus exhibits the enormous thickness of 3,907 ft. The boring would have been continued in order to discover what description of deposit lay under the salt but for the mechanical difficulties connected with the further prosecution of the operations. During the progress of this interesting work repeated and careful observations were made of the temperature at various depths. The results confirm very closely those which have been already arrived at under similar circumstances.

HYDRO-ELECTRIC CABLES.—The journal "Les Mondes," which often holds forth upon marvels, has noticed a new one in a recent number. This is a proposed system for submarine telegraphic communication by means of a tube filled

with water. The invention is due to M. Ferdinand Tommasi, and models are exhibited at 69 Avenue de l'Alma. The tube is of copper $\frac{1}{16}$ of an inch diameter. The experiment is made with a length of 3,280 ft., and the inventor hopes to obtain, first, a speed of transmission of at least 600 signals a minute, even through a length of 1,000 miles; second, a simultaneous exchange of correspondence— that is to say, the facility of being able, by the same tube, to signal both ways at once; third, the facility for printing despatches; and fourth, a very small cost of construction.

The thread of water is in communication at each end with two pistons of the same diameter. One of these pistons is slightly pressed, and the motion is immediately transferred to the other piston. The tube and its pistons are in connection with an electro-magnetic apparatus to facilitate the transmission and the reception of messages.

COST OF THE HOOSAC TUNNEL.—An official report by the State Auditor to the Legislature of Massachusetts states the cost to State since it took possession, to be, up to January 1, 1872, $7,985,501. This sum includes what has been paid on the original contract, $1,477,905. It is estimated that it will yet cost for a railway from the west portal to North Adams $164,635; for interest on loans, premiums, commissions, etc., $12,627,599, a total of $12,792,234, up to March 1, 1874. Some deductions are to be made from this for sinking fund, rents, etc.; amount not stated, but is not very large. This is, probably, the most exact estimate yet made of the cost of the "great bore" to the Massachusetts tax-payers.

MEMPHIS TUNNEL.—Not content with dyking, bridging, and traversing the Father of Waters in every direction, a tunnel is, as our readers have already been informed, seriously projected under it at Memphis, to cost $5,000,000. Details of construction, etc., are not yet fully or accurately given, so far as we are aware.

ORDNANCE AND NAVAL.

FIELD GUNS AND AMMUNITION.—The "Militair Worhenblatt" gives an account of the quantity of field ammunition which was spent by the German artillery during the last campaign in France. According to it the Prussian artillery, including the Baden and Hesse regiments, comprised 79 light, 78 heavy, and 38 horse batteries, besides 19 light, and 10 heavy reserve batteries, which were only formed after the war was declared—together, 224 field batteries, of 6 guns each, or 1,344 guns. The field guns are of two calibres, the light and heavy, with a bore of 8 centimetres, the heavy of 9 centimetres. They fired during the whole campaign 267,975 rounds in all, which is far less than is generally believed; the light batteries 112,770, the heavy 107,126, and the horse batteries 48,079 rounds, or each gun fired, on an average, 199 rounds, of which number each light gun fired 191, each heavy 203, and each horse 210 on an average. As the batteries carry in the ammunition carriage of each 8-centimetre gun 157, and of each 9-centimetre gun 133 rounds, they consequently fired, the light guns, 123 per cent.; the heavy, 153; and the horse, 134 per cent.—that is, they had to replenish 23, 53, and 34 per cent. respectively from the ammunition columns, which followed in the wake of the advancing armies. The Bavarian artillery consisted of 12 light, 22 heavy, and 2 12-pounder batteries, or 216 guns, which spent 56,211 rounds, or as much as 260 rounds per gun, while the Saxons had 48 8-centimetre guns, and 48 9-centimetre guns, and fired 8,007 and 7,514 rounds respectively, or 167 and 157 per each light or heavy gun, or 162 rounds on an average. The figures of Wurtemberg are not yet published, but may be estimated at three-fourths of those shown by Saxony. Thus the total of ammunition spent would be for the whole German field artillery about 350,000 rounds, and if, allowing one-half to light, and half to heavy guns, and the weight of light shells to be 9 lbs., that of heavy shells, 15.3 lbs., English, the weight of all ammunition fired is equal to 1,933 tons, or out of the number of 1,728 guns, each gun has, on an average, spent 1.119 ton of iron shells.

BOOK NOTICES.

DRAWING FOR BRICKLAYERS: Containing the Constructive Principles of Brickwork, and the Method of Drawing each subject, together with the Elements of Freehand, Subject and Plan Drawing. With two double and thirty-two single pages of illustrations. Adapted for Architectural Drawing. Copies drawn on wood by the author. By ELLIS A. DAVIDSON. London: Cassell & Co. 1872. For sale by Van Nostrand.

This is a work which ought to be not only useful, but widely used. The system in it corresponds with that pursued by its predecessors, "Drawing for Carpenters and Joiners," and "Drawing for Stonemasons," and thus the instruction is not confined to linear drawing solely, but includes also a certain amount of freehand and model-drawing, whilst the constructive principles of the various studies are given as fully as the size of the book would allow. The author acknowledges his obligations to Colonel Wray, R. E., Government Examiner in Science, for his placing "a mass of material at his disposal, and for his important and valuable original suggestions." We are satisfied as to the general completeness and accuracy of this book, as of all the author's productions of a similar sort.

AIR AND RAIN, THE BEGINNINGS OF A CHEMICAL CLIMATOLOGY. By ROBERT ANGUS SMITH, Ph.D., F.R.S., F.C.S. London: Longmans, Green & Co. For sale by Van Nostrand.

This publication is the fulfilment of a promise made to the public eight years since by the author. Chemistry up to the present time has not taken its full share in the work of sanitary inquiry and improvement; it ought, as Dr. Smith remarks, to be able to relieve medical men of much of their heavy responsibility. His own book will certainly aid to bring about this in no small degree. Its purport is to show that there are impurities in an atmosphere which may be discovered by chemical analysis, and that the senses and general impressions are not at fault when they testify to the peculiarities of a town atmosphere.

THE LE BOULENGE CHRONOGRAPH. By Brevet Capt. O. E. MICHAELIS, First Lieut. Ordnance Corps, U. S. A. New York: D. Van Nostrand.

Of this new work for the military service the object is best explained by the author's introduction:

"Up to the present time, all successful applications of micro-chronometry to the science of gunnery have been based upon the use of electricity as the determining agent.

Captain Le Boulengé's instrument is no exception. The time between two events is ascertained by noting the distance of the free fall of a heavy body during the interval, the beginning and end of this distance being made to accord with the occurrence of the events by means of the galvanic current.

With the exception of the Schultz chronoscope, an instrument too delicate in its details for ordinary use, the most noteworthy ballistic micro-chronometers of the last fifteen years have used the pendulum as the immediate measurer and recorder of the time—time deduced, of course, from the duration of constrained motion; and the improvements in these pendulum instruments during the past decade may be summed up as attempts to mitigate the errors due to the circumstances of constraint, *i. e.*, to the method of suspension.

It remained for Captain Le Boulengé, one of the most scientific and ingenious Ordnance officers of the Continent, in the service of Belgium, whose sons have already done so much for ballistic science, to devise an apparatus, simple in its construction, accurate in its operation, which eliminates entirely every error due to a constrained fall.

Stated epigrammatically, he reduces the pendulum to its bob, and allows it to fall freely.

THE INSTRUMENT.

The chronograph of Captain Le Boulengé can be used not only as a micro-chronometer, but directly as a velocimeter. To obtain velocities at once, two electric circuits are established a fixed distance, say 50 metres apart, in such a manner as to be successively broken by the projectile in its flight. The first current circulates through an electro-magnet, whose armature is a long cylindrical rod, called the chronometer, furnished with two enveloping zinc tubes, called recorders. The second current passes by another electro-magnet, whose armature, a shorter rod, is called the registrar. The third active element of the instrument is the indenter, consisting of a circular knife fixed in a mainspring, which can be cocked by means of a catch on a lever.

On the breaking of the first circuit, the chronometer falls vertically; on the rupture of the second, the registrar falls in its turn, depresses the free end of the lever, and thus releases the mainspring; the knife juts forward, strikes the falling chronometer, and indents the upper recorder. A very simple relation holds between the dent thus obtained and the velocity of the projectile which caused it. Even with this brief description, a moment's thought will show that the lower the velocity, the higher up shall the recorder be indented.'

A set of tables are given for use when applying the instrument.

Plates, with full letter-press descriptions, make the construction of the minutest details exceptionally clear.

LIFE ASSURANCE AND SAVINGS BANKS. By J. HOWARD VAN AMRINGE, A. M. New York: D. Van Nostrand.

This pamphlet affords a thoroughly popular exposition of the principles upon which are founded corporations for Life Assurance and Savings Banks.

Prof. Van Amringe has proven himself, by this lecture, a master of the art of elucidation. Nothing could be plainer than the demonstration here afforded that life assurance is founded upon well-understood laws, and nothing, in a mathematical way, could be more interesting to the average reader.

It seems proper, if not necessary, to say to our readers that they can find nothing in the above lecture to suggest in any way the labors and devices of those agents of slow torture who talk in behalf of life insurance companies all over the country.

THE GRAND TRAVERSE REGION. By ALEX. WINCHELL, A. M. Ann Arbor: Chase.

This is a report by the well-known geologist on the geological and industrial resources of the lower peninsula of Michigan. The Prof. does not confine himself to an account of rocks and soils, but records his observations on botany, zoology, topography, and climate.

Though the report is of local rather than general interest, it adds no little to the sum of our knowledge of the natural history of our country, with the endorsement of a leading authority.

EASY RULES FOR THE MEASUREMENT OF EARTHWORKS. By ELLWOOD MORRIS, C. E. Philadelphia: T. R. Callender & Co. For sale by Van Nostrand.

This is essentially a treatise on the history and use of the Prismoidal Formula. It fully discusses all the proper modifications of this famous formula which may be safely used in the computation of earthwork.

To the mathematical student the treatise will prove interesting, while to the careful engineer who is desirous of understanding the limits of error in his approximate calculation, the work will be found of decided value.

POTTERY; Observations on the Materials and Manufacture of Terra-Cotta, Stone-Ware, Fire-Brick, Porcelain, Earthen-Ware, Majolica, and Encaustic Tiles. By ARTHUR BECKWITH, C.E. New York: D. Van Nostrand.

This is a report upon the observation made at the Exhibition of 1871, and affords a concise summary of the different products of ceramic art.

The most valuable part of the report undoubtedly is, that which is devoted to the materials employed, and the processes of manufacture.

No portion of the report is so technical as to be without interest even to the unscientific reader, while the account of the modern reproduction of the ancient and highly prized wares is of great interest to all classes.

A table of the constituents of celebrated fire clays will be found valuable to all who are interested either in natural or artificial refractory compounds designed to resist heat.

MISCELLANEOUS.

CLASSIFICATION FOR THE INTERNATIONAL EXHIBITION OF 1876.—The United States Centennial Commission, at its last meeting, adopted, as the basis of the system of classification, ten comprehensive divisions, named *Departments*, as follows:

Department 1. Raw Materials, Products of the Soil, of the Mine, and of the Sea, and their Immediate Derivatives.

Department 2. Materials, the Result of Manufacturing Processes, Chemical Compounds, Manufactures, and Products.

Department 3. Textile and Felted Fabrics, including Ready-made Clothing and Costumes, etc.

Department 4. Furniture and Manufactures of General Use.

Department 5. Tools, Implements, Machines, and Processes.

Department 6. Apparatus and Methods of Transportation.

Department 7. Apparatus and Methods for the Increase and Diffusion of Knowledge.

Department 8. Civil, Mining and Military Engineering, Public Works and Architecture.

Department 9. Fine Arts.

Department 10. Objects illustrating the Methods and Results of Efforts for the Improvement of the Physical, Intellectual, and Moral Condition of Man.

Each of these Departments will be subdivided into ten groups, and each group into ten classes, thus giving 100 groups and 1,000 classes.

The Departments will be numbered from I. to X., and the Groups from 1 to 100, while the Classes will be numbered from 1 to 1,000. Thus the number of any Class will at once indicate the Groups and the Department to which it belongs.

The arrangement of the various objects in the building will not only be in accordance with this systematic classification, but will be also geographical, the two elements being combined, as in the Exposition of 1867, by means of parallel galleries or halls, crossed at right angles by passage ways. The products of any country can thus be kept together, while at the same time they are distributed in the appropriate Groups

In the formation of the system, the governing idea has been to group together objects in the following order:

1. The natural products useful to man, or the basis of manufacture.

2. The manufactures and results of the combinations of these products.

3. The means and appliances by which such results have been accomplished.

4. The resultant effects of such productive activity.

This is a comprehensive general expression of the classification. The raw materials are placed first, and then in succession the results of their use by man, leaving until the last the higher achievements of intellect and imagination.

It is a natural and simple classification, and is calculated to show effectively the development of man, the progress of the arts and of civilization.

LEAD IN THE UNITED STATES.—Since the breaking out of the Californian gold fever, twenty-three years ago, the western lead mines, which had up to that period supplied all the wants of the United States, have attracted very little notice, and the production of the States of Wisconsin, Iowa, and Illinois, has rapidly fallen off, as may be seen by the following figures, which give the quantity of lead shipped from the Upper Mississippi mines, viz:—

		Pigs.	Tons.
From 1822 to 1831	....	664,118 or	28,244
" 1832 " 1841	....	1,591,958 "	35,718
" 1842 " 1857	....	6,170,857 "	215,979
" 1852 " 1861	....	4,609,553 "	161,334
" 1862 " 1871	....	2,419,985 "	84,700

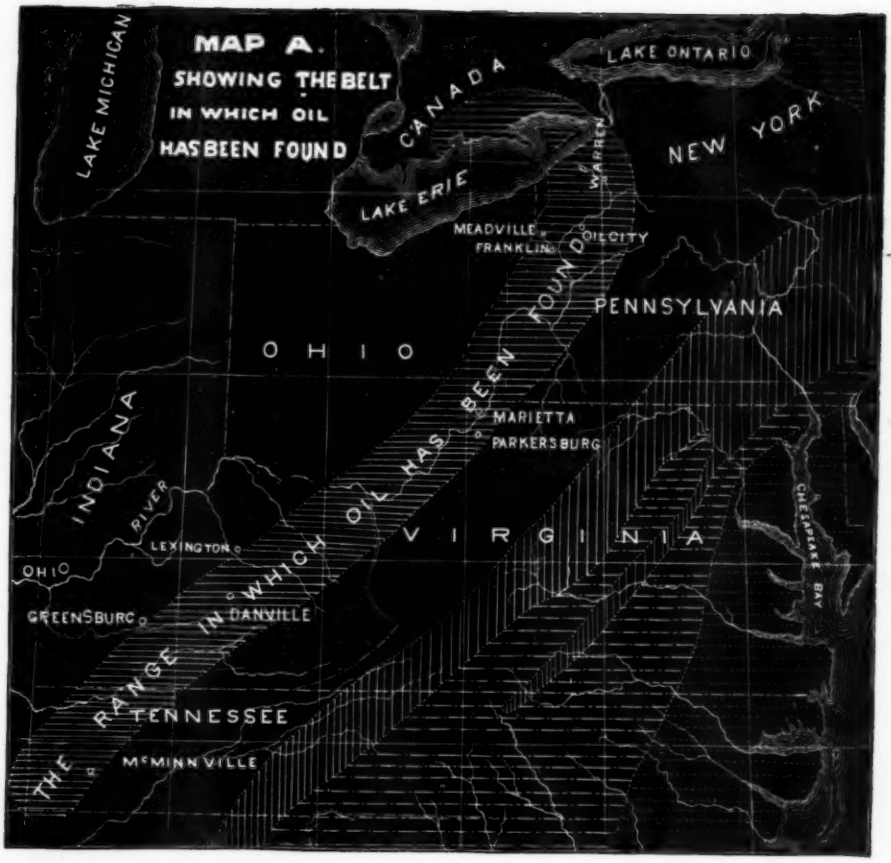
It will be observed that from 1852 to 1861, there was a decrease of 25$\frac{3}{11}$ per cent., and from 1862 to 1871 there was a further decrease of 47 per cent. It is not to be supposed that the mines are exhausted; on the contrary, it is known that many thousands tons of ore exist in mines that have not yet been touched, and which are held by the owners for prices that are not at present attainable, otherwise the production of lead might have been greatly increased, and a large amount of money saved that has been paid meanwhile for foreign lead (nearly $400,000,000 were paid during the last year), besides furnishing labor to thousands of hands. The imports of foreign lead into New York alone have been as follows:—

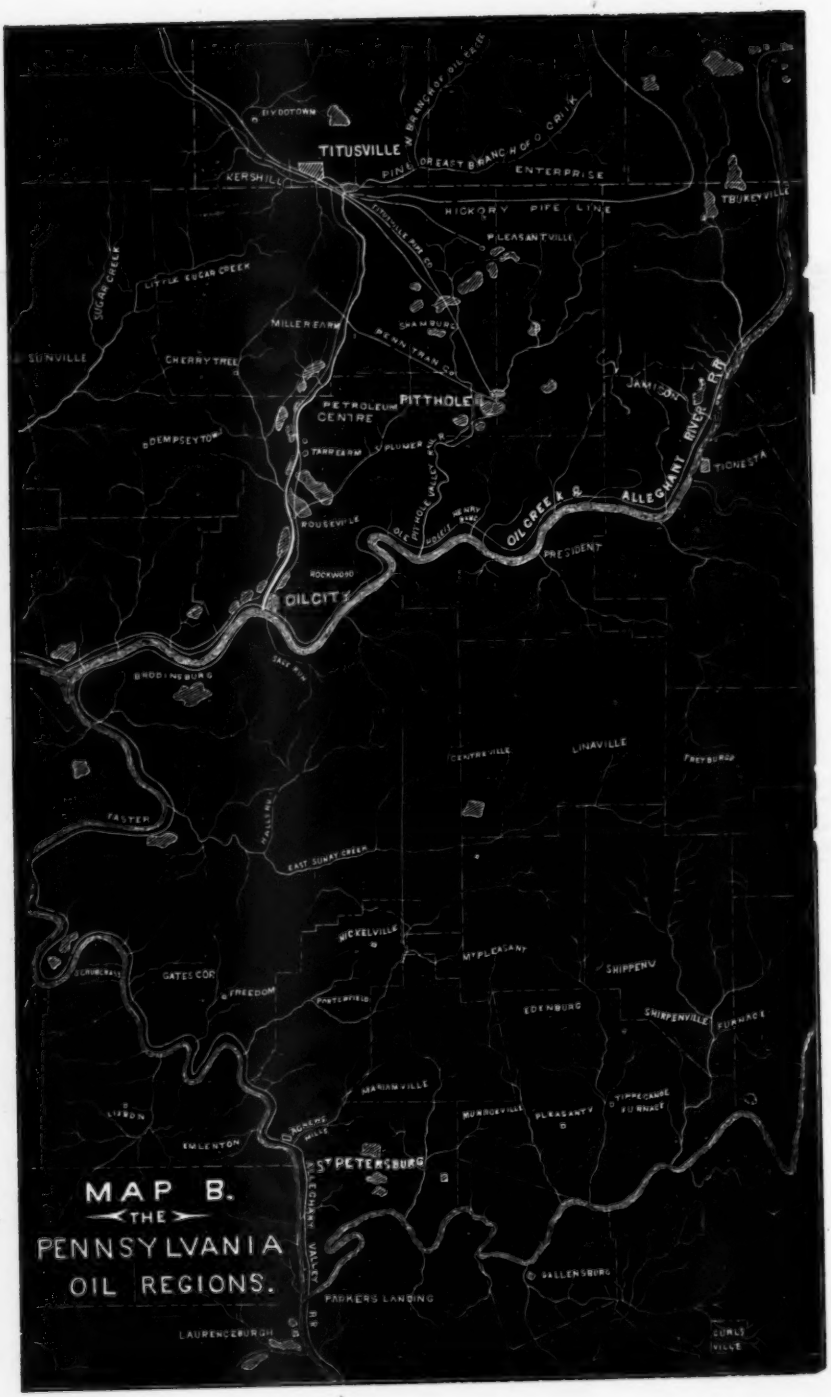
	Pigs.
1852	272,657
1854	400,020
1856	301,536
1858	254,573
1860	362,031
1862	613,088
1863	212,661
1864	462,272
1965	226,791
1866	449,307
1867	415,757
1868	385,277
1869	535,790
1870	496,157
1871	516,912

A pig of foreign lead is fully equal to two of American.

NORTH AMERICAN TIMBERED LAND.—British Columbia is said to contain about 100,000 square miles of timbered land; Alaska, 150,000 square miles; Washington Territory and Oregon, 65,000 square miles; and California, 40,000 square miles. In Washington Territory, as in British Columbia, Douglas fir, which is very valuable for shipbuilding, predominates. The constant using up of available trees for commercial purposes, the devastating effects of forest fires, and the reckless waste of individuals are making serious inroads upon the forests of British Columbia.

COAL IN SWEDEN.—M. Braconnier de Macar, president of the Liége Coal Mines and Metallurgical Association, accompanied by M. Maréchal, honorary engineer of the association, has visited Sweden in order to ascertain the richness of the coal bearings of the Skanian fields, of which very favorable reports have been made. The bearings are considerable, and M. Braconnier has acquired several concessions, and proposes to commence the extraction of coal as soon as possible.


MAP A.
SHOWING THE BELT
IN WHICH OIL
HAS BEEN FOUND
LAKE MICHIGAN
CANADA
LAKE ONTARIO
NEW YORK
LAKE ERIE
WARREN
MEADVILLE
FRANKLIN
OIL CITY
PENNSYLVANIA
OHIO
INDIANA
MARIETTA
PARKERSBURG
RIVER
LEXINGTON
VIRGINIA
CHESAPEAKE BAY
OHIO
GREENSBURG
DANVILLE
THE RANGE IN WHICH OIL HAS BEEN FOUND
TENNESSEE
McMINNVILLE


TITUSVILLE
KERSHILL
PLEASANTVILLE
HICKORY PIPE LINE
ENTERPRISE
TIDIOUTE
TIONESTA
SUNVILLE
CHERRY TREE
MILLER FARM
SHAMBURG
PETROLEUM CENTRE
PITTHOLE
DEMPSEYTOWN
TARR FARM
PLUMER
ROUSEVILLE
ROCKWOOD
OILCITY
PRESIDENT
OIL CREEK & ALLEGHANY RIVER R.R.
BRIDGINSBURG
CENTREVILLE
LINAVILLE
FREYBURG
EAST SUNNYCREEK
WICKELVILLE
MYERSDALE
GATESCOR
FREEDOM
PORTERFIELD
EDENBURG
SHIPPENVILLE
SHIPPENVILLE FURNACE
MARIANVILLE
LISBON
EMLENTON
ROBERTS VILLE
MUNDYSVILLE
PLEASANTV
TIPPECANOE FURNACE
ST PETERSBURG
FARMERS LANDING
FALLENSBURG
LAURENCEBURGH
CURLS VILLE
MAP B.
THE
PENNSYLVANIA
OIL REGIONS.